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Golden-Crowned Snake (*Cacophis squamulosus*) from the South Coast of New South Wales.
(Photo: G. Daly). See article on the herpetofauna of Morton National Park on page 5.



Mating Southern Water Skinks (*Eulamprus heatwolei*). See article on mating behaviour of this species on page 25.

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CARRION SCAVENGING BY THE TIGER SNAKE (*NOTECHIS SCUTATUS*)

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INTRODUCTION

The diet of most Australian elapid snakes is dominated by live prey (Shine, 1991), and most species are active foragers, although there are exceptions to this, such as Death Adders (*Acanthophis* spp.), which are ambush predators. Feeding upon carrion is rarely observed in elapids, although Red-bellied Black Snakes (*Pseudechis porphyriacus*) have been observed feeding on road-killed Common Blue-tongued Lizards (*Tiliqua scincoides*) (N. Clemann, pers. obs.) and Bedford (1991) reports likely carrion feeding by Mulga Snakes (*Pseudechis australis*). DeVault and Krochmal (2002) reviewed the literature regarding scavenging by snakes and, although they documented numerous published accounts of this behaviour, most accounts pertain to other snake families, and only one account of carrion scavenging by elapids is documented (that observed by Bedford, mentioned above).

The diet of the Tiger Snake (*Notechis scutatus*) consists mainly of frogs, although this species will also take reptiles, birds and mammals (Shine, 1977, 1991). However, insular populations of Tiger Snakes often do not have access to frogs, and their diets consist of lizards, small mammals and birds, the proportions of which tend to vary with the size of the snake (Schwaner, 1985; Schwaner & Sarre, 1988; Bonnet 1999). Feeding on carrion by wild Tiger Snakes has rarely been reported (Fearn, 1993).

OBSERVATIONS

We undertook a project comparing spatial patterns of resident and translocated Tiger Snakes (Butler *et al.*, 2005) at Westerfolds Park, a large semi-natural parkland adjacent to the Yarra River, approximately 16 km north-east of Melbourne. During this project, on 7 November 2002, one of the Tiger Snakes that we caught (male, snout-vent length 100 cm, total length 116.5 cm) regurgitated a small (127 g) European Rabbit (*Oryctolagus cuniculus*). After regurgitating the rabbit, the snake weighed 576.1 g. The regurgitated rabbit was riddled with maggots, indicating that it was dead at the time it was consumed by the snake. Whilst radiotracking this particular snake we regularly recorded it using rabbit warrens as shelter sites. On one occasion, one of us (HB) observed this snake basking at the entrance to a rabbit burrow. At this time the snake had a very large mid-body bulge, suggesting that it may have recently consumed another rabbit.

On another occasion in 2003 we found a large, dead rabbit at Westerfolds Park that appeared to have saliva covering its head and neck. This rabbit was situated adjacent to the shelter site of another large male Tiger Snake that we were tracking. We suspect that the snake had attempted to eat this rabbit, but had been unable to swallow such a large prey item. We also encountered a Tiger Snake in the process of consuming a Noisy Miner (*Manorina melanocephala*). In both of these encounters we believe that the potential prey were alive when attacked.

DISCUSSION

Although Tiger Snakes are known to consume a variety of vertebrate prey types, including mammals, the exotic European Rabbit has rarely been recorded as a prey item (Fearn, 1993), despite the abundance of this pest in the areas where these species co-occur. At our study site rabbits are very common, and we frequently recorded Tiger Snakes using rabbit burrows as shelter sites. It is possible that large Tiger Snakes occasionally take small, live rabbits in this park. Rabbits may be a convenient and energetically valuable food source for these snakes. They are highly fecund and grow quickly (Menkhorst, 1995), and may thus present predators with a range of potential prey sizes. Because snakes are secretive animals, and observations of feeding in the wild are rare, we do not know whether Tiger Snakes often scavenge dead prey, although Fearn (1993) suggests that feeding upon carrion by Tiger Snakes may occur more frequently than supposed (based on his observations of captive and wild specimens eating dead rodents and birds).

Previous studies on the mainland of Australia have shown that frogs are the most common prey of Tiger Snakes (Shine, 1977, 1991). Our study was conducted at a time of protracted drought when frog abundance and activity was probably low. Other potential terrestrial prey items for Tiger Snakes at the study site were exotic rodents and scincid lizards. Although Westerfolds Park contains remnants of native vegetation, it is highly modified. Consequently, the park's diversity of lizards is probably reduced due to habitat loss and modification. However, the park retains an abundance of common, generalist lizards, the most abundant of which are Garden Skinks (*Lampropholis guichenoti*) and Blue-tongued Lizards (*Tiliqua scincoides* and *T. nigrolutea*). Garden Skinks have previously been recorded as prey items of Tiger Snakes (Shine, 1977), however their small size means that they would only be substantial prey items for small Tiger Snakes. Currey (2004) weighed 34 adult *T. scincoides* and 19

adult *T. nigrolutea* caught at Westerfolds Park between October 2003 and January 2004, recording mean masses of 268.8 (± 11.75 , range 101 – 400) and 331.8 (± 15.57 , range 201 – 500) grams respectively. Consequently, these large skinks potentially provide a substantial food resource for Tiger Snakes at the study site, their weights range beyond that of the regurgitated rabbit, and they are active over similar seasons and daily times to the snakes (Currey, 2004). However, we do not know for certain that the Tiger Snakes eat Blue-tongued Lizards at this site, and speculate that, in such a modified environment, where both native and exotic prey are abundant, Tiger Snakes may have a diverse, opportunistic diet.

DeVault and Krochmal (2002) suggest that olfaction is probably the overriding sensory modality used by snakes to locate carrion, and that the incidence of scavenging is probably underestimated (and under-appreciated) by most herpetologists. They conclude that scavenging may be a deliberate and valuable supplementary feeding strategy by many snake taxa. Our observations lend weight to this conclusion.

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REPTILES AND AMPHIBIANS OF MORTON NATIONAL PARK AND ENVIRONS ON THE SOUTH COAST OF NEW SOUTH WALES

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ABSTRACT

Systematic surveys for reptiles at 100 sites and amphibians at 42 sites in the broader area of Morton National Park on the south coast of New South Wales were conducted between 1997 and 2005. A total of 27 species of reptile and 14 species of frog was detected during systematic surveys and an additional 16 species of reptile and 11 species of frog were found opportunistically. The area contains a high species diversity of reptiles and amphibians. Five species listed under the Threatened Species Conservation Act (1995) were detected: the Broad-headed Snake *Hoplocephalus bungaroides*, Heath Monitor *Varanus rosenbergi*, Heath Frog *Litoria littlejohni*, Giant Burrowing Frog *Heleioporus australiacus* and Stuttering Frog *Mixophyes balbus*. The area has significant populations of *H. bungaroides* and *L. littlejohni*.

Although the area has a wide range of habitats, quantitative surveys indicated that north-facing ridgelines containing sandstone outcrops had the richest species diversity of reptiles and creeks that flow through heath/woodland had the highest species diversity of amphibians.

In the Sydney Basin bioregion, Hawkesbury Sandstone peters out as surface rock as an overlay of Nowra Sandstone in the north-west of the study area. Several species of reptiles and frogs have a distribution that is highly associated with weathered sandstone outcrops along the escarpment, which is composed of the above two formations. The southern limit of some species of reptile occurs within the area where Nowra Sandstone occurs as surface rock.

The Stone Gecko *Diplodactylus vittatus*, Cunningham's Skink *Egernia cunninghami*,

White's Skink *E. whitii*, Freycinet's Frog *Litoria freycineti*, Heath Frog *Litoria littlejohni*, Pobblebonk *Limnodynastes dumerilii* and Haswell's Frog *Paracrinia haswelli* were detected on the sandstone plateau south of the Shoalhaven River but were not found in similar habitat north of this river. The Shoalhaven and Kangaroo Rivers appear to have impeded the dispersal of these species.

INTRODUCTION

Morton and the adjoining Budawang National Park (NP) are situated on the south coast of New South Wales between 34°37' and 35°33'S and 150° and 150°35'E. Morton NP was gazetted in 1937. At that time 24,291 hectares encompassing the Yarrunga and Bundanoon Creeks augmented the existing 3,117 hectares of Tallowa Primitive Area Reserve (Watson, 1987). Since that time many additions have been made and the park currently totals 189,668 hectares. Morton NP covers an area from Fitzroy Falls in the north to Milton in the south. The park adjoins several other reserves and State Forests (Table 1), that constitute the study area.

The reptiles and amphibians of Morton National Park have received some previous study by Jenkins (1987). Other surveys in the region either targeted select species of amphibians (Daly, 1996, 1998) or reptile (Webb & Shine, 1988) or were conducted in nearby areas (Murphy, 1997; Murphy & Daly, 1998).

The aim of the present paper is to document the regional distribution of reptile and amphibians in relation to environmental variables. Quantitative surveys using standard survey methods allowed a measure of relative species diversity and abundance. The zoogeography

of the herpetofauna is considered in a regional context and the possible routes of colonisation for select species discussed. Comments are given on species currently listed on the Threatened Species Conservation (TSC) Act

(1995) as several are habitat specialists.

METHODS

Reptiles and amphibians were surveyed in sixteen National Parks (NP), Nature Reserves

Table 1. Distribution of survey sites by Reservation/State Forest in the Shoalhaven region of New South Wales. T = targeted and opportunistic surveys. Elevations in metres.

Reservation Unit	Total Area (hectares)	No. Reptile Sites	Min. Elevation	Max. Elevation	Mean	Frog Sites	Min. Elevation	Max. Elevation	Mean
Bangalee Reserve	127	T	0	120		T	0	120	
Barclay Reserve	21	T	160	430		1	200	200	200
Barrengarry NR	21	1	200	200	200	T	200	200	200
Bomaderry Creek NR	230	T	0	50		T	0	50	
Budawang NP	23,787	T	100	1100		T	100	1100	
Budgong NP	1,022	T	50	250		2	40	50	45
Currawan SF	12,026	6	120	425	263	6	40	120	60
Jerrawangla NP	4,013	T	170	490		5	160	370	225
Kangaroo River NR	126	2	90	100	95	T	90	100	95
Morton NP/Crown	189,668	73	80	770	393	9	100	740	525
North Brooman SF	3,643	3	65	130	315	2	60	70	65
Parma Creek NR	3,486	3	165	200	185	7	90	170	165
Red Rocks NR	669	3	570	600	583	1	570	570	570
Triplarina NR	158	T	40	50		T	40	50	
Yatheyattah NR	19	T	20	80		1	30	30	30
Yerriyong SF	6,730	3	75	95	80	7	70	80	70
Freehold	140	6	100	400	200	1	100	100	100
Total	245,886	100			288	42			187

(NR) and State Forests (SF) on the south coast of New South Wales. The study area formed a near contiguous block of bush that is located north of Batemans Bay (Braidwood Road), south of Kangaroo Valley (Moss Vale Road) and west of the Princes Highway. The bushland is interrupted by several roads and the Clyde River, Shoalhaven River/Kangaroo River and associated Tallowa Dam. The total area surveyed covered some 245,886 hectares (Table 1).

Opportunistic sightings of reptiles made by third parties are included in the assessment so that a more comprehensive account of the area's biodiversity was achieved.

Description of the study area

The bulk of the study area lies within Budawang and Morton NPs that are adjoining reserves situated west of Nowra on the south coast of New South Wales (Figure 1). Although the altitude of these reserves ranges from 20–1100 m AHD the central sandstone plateau is mostly 500 m AHD.

Geologically the area is predominantly Permian sandstones, siltstones and conglomerates (the Shoalhaven Group) of marine origin and is part of the southern most extent of the Sydney Basin. The deeply eroded gullies and sandstone bluffs of the Clyde River, Kangaroo River and Shoalhaven River escarpments are prominent features in the landscape.

The sandstone bluffs are derived from separate geologic series: Hawkesbury Sandstone and Nowra Sandstone. Hawkesbury Sandstone appears as a contiguous band of surface rock along the upper escarpment of Yarrunga Creek, Bundanoon Creek and sections of the Shoalhaven River, with isolates in Red Rocks NR. Where the Hawkesbury Sandstone peters out it is in very close contact with the Nowra Sandstone (west of Lake Yarrunga).

The study area is divided into three subunits because the major drainage lines have eroded the base geology into easily discern-

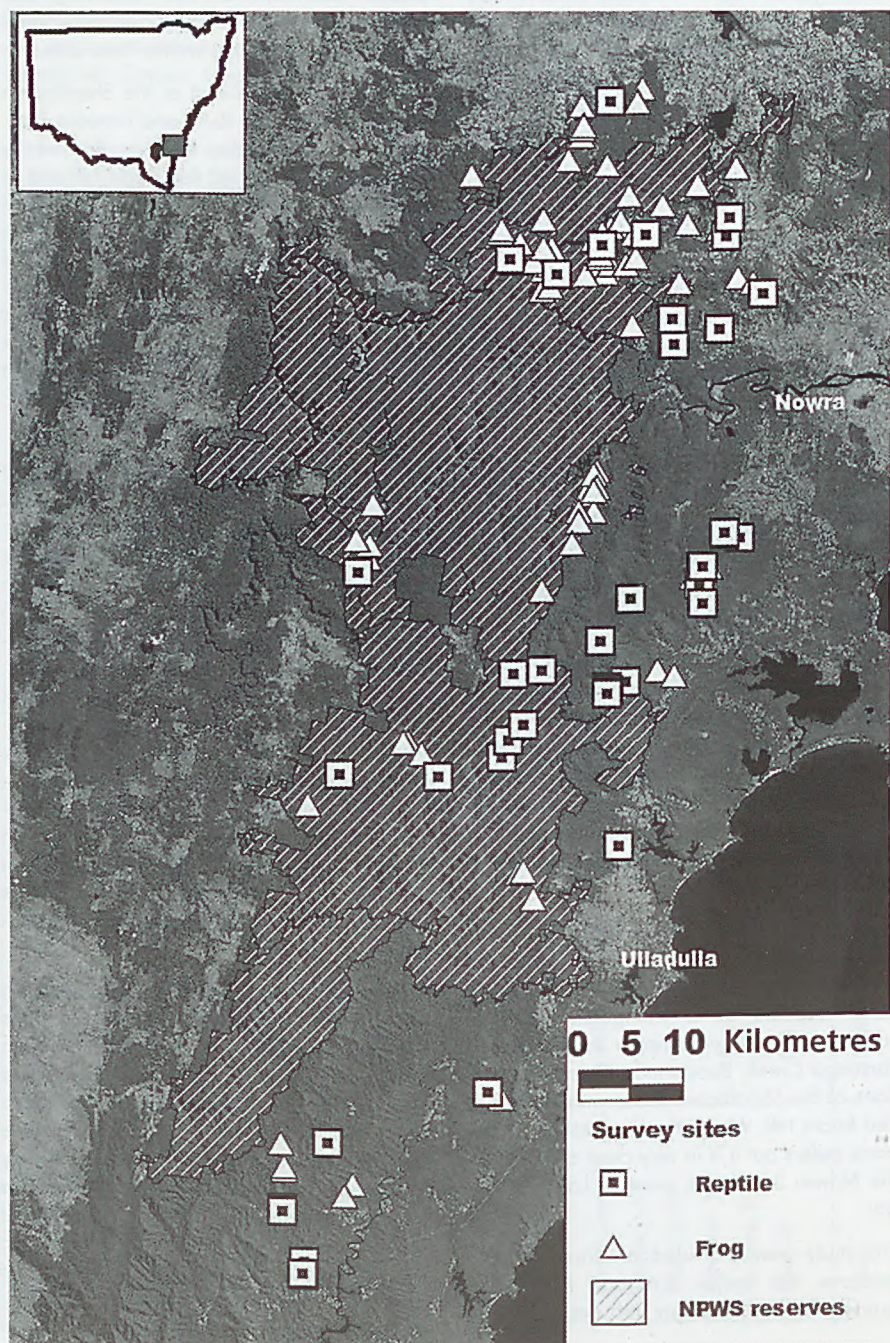
able units that have a bearing on some species distributions. The following are descriptions of the geology and associated vegetation communities within these areas.

One area lies north-east of the Shoalhaven River and Kangaroo River and includes Bangalee Reserve, Barclay Reserve, Bomaderry Creek NR, Budgong NP, Red Rocks NR and a portion of Morton NP. Another area is located north-west of Shoalhaven River/Kangaroo River (Kangaroo River NR and portions of Morton NP and Barrengarry NR) and the third lies south of the Shoalhaven River and encompassed Budawang NP, Parma Creek NR, Jerrawangla NP, Triplarina NR, North Brooman SF, Currowan SF, Yattelyattah NR, Yerrilyong SF and most of Morton NP.

In the first area, to the north-east of the Shoalhaven River and Kangaroo River, the prominent landforms include the Cambewarra Range and rocky escarpments beside the Shoalhaven and Kangaroo Rivers. The highest elevations (circa 600 m AHD) on the Cambewarra Range (Red Rocks NR) have isolated residual outcrops of Hawkesbury Sandstone (Hazelton, 1993). These are underlain by moderate to steep hills formed of Cambewarra Laterites and Budgong Sandstone. The escarpments beside the Shoalhaven and Kangaroo Rivers are formed of Nowra Sandstone. Soils of volcanic origin occur on Emery's Plateau and Cambewarra Mountain and much of the surrounding area have enriched soils based on laterites and mudstones.

Woodland (Silvertop Ash *E. seiberi*) and heath grows on the Hawkesbury Sandstone in areas with shallow soils. Woodland (Grey Gum *Eucalyptus punctata*, Scribbly Gum *Eucalyptus sclerophylla* and Red Bloodwood *Corymbia gummifera*) occurs on the Nowra Sandstone along the edge of the escarpment and Sydney Peppermint *Eucalyptus piperita* often grows below the escarpment. On the more fertile laterites there is tall open forest (Blue Gum and Turpentine) and subtropical closed forest beside the creeks and protected benches, especially on volcanic soils. Much of the flat

Figure 1. Location of reptile and frog survey sites.



land that has fertile soils has been cleared for agriculture.

In the second area, to the north-west of the Shoalhaven River and Kangaroo River, the prominent landforms include the deeply eroded gullies created by Yarrunga and Bundanoon Creeks and the Shoalhaven and Kangaroo Rivers. The area also includes the prominent rocky escarpments of Fitzroy Falls, Marla and Cumburmurra.

Hawkesbury Sandstone occurs on the highest elevations (circa 600 m AHD) but peters out near Cumburmurra. The Nowra Sandstone underlays the Hawkesbury Sandstone and forms the escarpment beside the Shoalhaven and Kangaroo Valley Rivers. The Hawkesbury Sandstone has a contiguous, albeit thin outcrop from Cumburmurra north along the escarpment to larger outcrops at Budderoo NP, Barren Grounds NR and the Sydney Water Catchments behind Wollongong. The sandstone of these different formations comes into contact on the Cumburmurra plateau.

Woodland and heath grows on the Hawkesbury Sandstone and Nowra Sandstone (Grey Gum, Scribbly Gum). On the more fertile Barrangary soils there is tall open forest (Blue Gum *E. saligna* x *botryoides*) and warm temperate closed forest beside the creeks and protected benches. Much of the land that has fertile soils has been cleared for agriculture.

In the third area, to the south of the Shoalhaven River, the prominent landforms include the deeply eroded gullies created by the Shoalhaven and Clyde Rivers. The various plateaus, which cover a large portion of this area, are primarily underlain with Nowra Sandstone (see Snedden, 1987). There are small occurrences of soils derived from volcanic activity at "The Vines" and at Sassafras. To the south there is Currockbilly Mountain and the Budawang Range, which are formed from metamorphic quartzites (Snedden, 1987).

The vegetation of the sandstone areas is primarily heath, woodland, and open forest (Pickard, 1987). On the sandstone plateaus, sedgeland, heath and woodland predominate whereas tall open forest and closed forest occurs along some creek lines, protected gullies and in areas where the soil is of higher nutrient and depth. The main canopy species in the woodland and open forest are Red Spotted Gum *Eucalyptus mannifera*, *E. punctata*, *E. piperita*, *E. sclerophylla*, *E. sieberi* and *C. gummifera*.

The State Forests in the region generally had deeper soils and tall open forest. The common associations were Blue Gum and Spotted Gum *Corymbia maculata*.

Elevations of reptile transects ranged from 65-770 m (average 356 m, N = 100). Eleva-

Table 2. Number of diurnal reptile survey sites and topographic positions. Altitude is average then (range) in metres.

Topographic Position	No. sites	Altitude (AHD)
Ridge	61	404 (80-770)
Midridge	23	330 (60-760)
Gully	16	214 (60-740)
Total reptile searches	100	
Cage trapping Ridge	21	371 (120-770)
Cage trapping Midridge	23	342 (60-760)
Cage trapping Gully	15	224 (60-740)
Total cage trapping	59	

tions of frog transects ranged from 30-740 m (average 244 m, $N = 42$), although surveys for *Litoria littlejohni* were conducted primarily at sites above 120 m AHD as the species had not been found below 130 m AHD (White *et al.*, 1994).

Survey Methods for Reptiles

Stratification

The locations of survey sites were stratified by topographic position. Transects were placed along gullies, ridges and midridges. The selection of a gully, ridge and midridge attempted to sample variation in habitat based on moisture gradient (Table 2). Transects were separated by a minimum of 200 metres (usually over one kilometre) and located within 50-1000 metres of dirt roads or fire trails. To avoid the possibility of recounting individual animals adjacent sites were surveyed in immediate succession. The location (Australian Grid Reference 66 datum) of sites was determined by either a geographic positioning system or topographic maps.

Survey Methods

Reptile searches involved observing active animals as they basked or foraged, lifting loose rock and logs, decortivating bark and searching leaf litter. The search technique varied according to the habitat present at each site. In areas where there was a general absence of loose rock and downed timber the census involved searching for active animals.

Systematic surveys were based on sampling an area of approximately 50 x 100 metres (0.5 hectares). However, at ridgelines the surveys focused on finding inactive animals by lifting loose rock that occurred along the escarpment edge and hence these sites were more linear in shape.

Surveys were conducted for 60 minutes by one person or 30 minutes by two people. A total of 60 minutes search effort per survey was maintained. The methods follow those determined by the NSW National Parks and Wildlife Service for the purpose of the com-

prehensive regional assessment of forests in southern NSW.

A total of 100 sites were surveyed during late spring, summer to autumn between 1997 and 2003. Surveys were conducted between 0816 and 1650 hrs Eastern Standard Time (EST) at temperatures that ranged between 20-30°C.

Cage trapping was conducted for goannas at 59 of the 100 sites (Table 2) and at one targeted site where a goanna tunnel was located in mounded sandy soil. The cages (200 x 200 x 450 mm) were baited with chicken or sardines/oats/peanut butter and set for three consecutive days (except the targeted trap which was set for one day). Traps were checked daily.

Reptiles observed while conducting nocturnal frog searches, when travelling to and from sites or outside the survey period were recorded as opportunistic sightings.

Frog Surveys

The locations of survey sites were stratified over various altitudes (range of 40-740 metres, average 232) and vegetation communities. Systematic nocturnal searches were conducted between 1997 and 2003. Non-systematic surveys were conducted from 1995 to 2005 and often involved targeted diurnal surveys for the tadpoles of *Mixophyes balbus* and *Heleioporus australiacus* (Daly, 1996, 1998). Frogs detected while conducting reptile surveys were recorded as opportunistic sightings.

Diurnal Searches for Frogs

Diurnal surveys involved walking along creeks and looking for frogs, tadpoles and spawn. Frogs were identified by recognition of their species-specific call, tadpoles and spawn. Diurnal searches targeted tadpoles of the threatened species *Litoria littlejohni*, *Mixophyes balbus* and *Heleioporus australiacus* and were not conducted over standard time intervals. Diurnal searches were also made for frogs at fire dams and ponds created from quarrying activities. These searches involved

dip netting for tadpoles.

Nocturnal Surveys for Frogs

Nocturnal searches involved spotlighting approximately 250 m of creek for 30 minutes per transect. Fifty watt/12 volt spotlights were used to observe frogs, tadpoles and spawn. The methods primarily followed those determined by the NSW National Parks and Wildlife Service for the purpose of the comprehensive regional assessment of forests in southern NSW. Nocturnal surveys were stratified on habitat and temporal factors (breeding seasons).

A total of 42 sites were surveyed. Nine sites were surveyed in Currowan SF, Parma Creek NR, North Brooman SF and Morton NP between March 1997 and March 1998 as part of the comprehensive regional assessment (CRA) of forests in southern NSW. These surveys were conducted between 1927 and 2230 hrs EST at temperatures which ranged between 18–26°C (air).

Thirteen sites were surveyed for *M. balbus* in late spring to summer beside creeks that flowed through tall open forest/closed forest. These surveys were conducted from 12 October 1999 - 9 February 2000 between 1932 hrs and 2212 hrs EST at temperature that ranged from 15–24.6°C (air) and 14–23.3°C (water). During these surveys the calls of *M. balbus* were broadcast continually from a cassette player (Optimus CTR-116) while spotlighting (see Daly *et al.*, 2002).

Surveys for *Litoria littlejohni* were conducted in Parma Creek NR, Jerrawangla NP and Morton NP at sites which contained tall open forest/woodland and or heath on the sandstone plateau. Thirteen surveys were conducted over four nights between 3 September 2001 to 6 September 2001 and two additional sites in 2003. These surveys were conducted between 1824 and 2345 hrs EST at temperatures which ranged between 5.8–13.6°C (air) and 8.1–13.2°C (water).

The other five surveys were conducted on freehold land for the purpose of voluntary

conservation agreements or as part of general fauna surveys to ascertain the distribution and abundance of fauna.

Nocturnal searches were also made for frogs at fire dams and ponds (circa 20) created from quarrying activities. These searches involved spotlighting and identifying species by call.

Survey hygiene

For surveys conducted after 2001 the NSW NPWS hygiene guidelines for control of disease in frogs (NSW NPWS Threatened Species Management, 2001) were adhered to.

RESULTS

Plot data and opportunistic observations

A total of 837 individuals covering 27 species of reptile were observed (Table 3) during 100 hours of systematic survey; an additional ten species were detected opportunistically or during targeted surveys. The presence of four other species of reptile in the area was ascertained from other persons. Five species of reptile accounted for about 80% of detections: *Lampropholis delicata* (32%), *Eulamprus quoyii* (16%), *Oedura lesueurii* (12%), *Ctenotus taeniolatus* (9%) and *Lampropholis guichenoti* (8%).

A total of 499 individuals covering 13 species of frog were detected (Table 4) during 21 hours of systematic surveys of frogs. In addition tadpoles of *Heleioporus australiacus* were observed at one of the sites surveyed systematically. Other species only detected opportunistically or associated with dams were *Litoria caerulea*, *Lit. dentata*, *Lit. ewingii*, *Lit. freycineti* and *Lit. tyleri*, *Limnodynastes dumerilii*, *Lim. tasmaniensis*, *Uperoleia laevigata* and *U. tyleri*. Five species of frog contributed to about 90% of detections during systematic surveys: *Crinia signifera* (26%), *Litoria littlejohni* (23%), *Paracrinia haswelli* and *Lit. nudidigita* (19% each).

Environmental gradients/barriers and species assemblages

Three physiographic components had a bearing on species diversity and zoogeography. They were altitude (and hence temperature), physical barriers such as the Shoalhaven River and Kangaroo River and geology (microhabitat preferences).

An assemblage herein termed highland species, consisting of *Egernia saxatilis*, *Pseudemoia spenceri*, *Tiliqua nigrolutea*, *Austrelaps ramsayi* and *Drysdalia coronoides*, was detected above 425 m AHD. Two species, *Eulamprus heatwolei* and *Litoria ewingii*, normally found at higher elevations (above 400 m AHD) in the north (Tianjara-Sassafras) of the study area were found close to sea level at higher latitudes (i.e. further south of the study area near Batemans Bay). *Litoria littlejohni* was found only above 130 m AHD and is considered a highland species. Conversely lowland species such as *Litoria caerulea*, *Litoria jervisiensis* and *Litoria tyleri* were detected below 130 m AHD.

Diplodactylus vittatus, *Ctenotus robustus*, *Egernia cunninghami*, *E. saxatilis*, *E. whitii*, *Pseudemoia spenceri*, *Austrelaps ramsayi*, *Drysdalia coronoides*, *Litoria littlejohni* and *Paracrinia haswelli* were only detected to the south of the Shoalhaven-Kangaroo Rivers. Given that some of these species distributions are mediated in part by altitude, the absence of the remaining species, *Diplodactylus vittatus*, *E. cunninghami*, *E. whitii*, *L. freycineti* and *P. haswelli*, in the north-east portion of the study area suggests that either there has been localised extinction, the species occur at very low densities or the Shoalhaven-Kangaroo Rivers are a barrier to dispersal for some species.

More species of reptile were found at ridge sites than gully sites than midslope sites (total species 24 vs 15 vs 10 for ridge v gully v midslope; Table 3), probably reflecting the greater number of survey sites on ridgetops (Table 2). On average more individuals were detected on gully sites than ridge than

midridge sites (average number of individuals per transect 10.4 vs 8.5 vs 6.6). Average species richness was highest for ridge than gully than midridge sites (average number of species per site 4 vs 2.6 vs 1.6). Ridge sites often contained extensive areas of exposed rock and loose rock exfoliations (Nowra or Hawkesbury Sandstone) that provided refuge microhabitat. Ridge sites also received more solar radiation than midslope or gully sites because of altitude and/or reduced canopy cover due to the shallow soils and exposed rock. Ridge sites often contained an ecotonal range of vegetation with woodland and heathland on the ridge and taller forest immediately below the ridge.

Saxicolous species of reptile primarily found at ridge sites included *Oedura lesueurii*, *Varanus rosenbergi*, *Bassiana platynota*, *Cryptoblepharus virgatus*, *Ctenotus taeniolaetus*, *Egernia cunninghami*, *E. whitii*, *Demansia psammophis*, *Hoplocephalus bungaroides* and *Ramphotyphlops nigrescens*. Species of amphibian detected beside streams which flowed over sandstone escarpments and plateau areas included *Litoria citropa*, *Litoria littlejohni* and *Heleioporus australiacus*. In particular north facing aspects with loose sandstone rock on rock were utilised by *Oedura lesueurii*, *Cryptoblepharus virgatus* and *Hoplocephalus bungaroides*. In the southern portion of Morton NP sandstone outcrops were absent. With the exception of *Bassiana platynota* the above mentioned species were not detected in this area.

More species (13 vs 5) of amphibian were detected in heath-woodland than tall open forest-closed forest.

Limnodynastes tasmaniensis was only found on the western boundary of the study area. This species occurred on heavier soils in the southern tablelands. *Litoria fallax* appears to be translocated into the study area and during the course of this survey has been observed to spread from a few farm dams to now occupy a large portion of Kangaroo Valley. Other presumably translocated populations occur on the coastal plain.

Table 3. Number of reptiles observed during systematic surveys. Additional species not recorded during systematic surveys are indicated by letters: † - observed opportunistically by author, a = G. Merdith, e = S. Evison, g = P. German, j = Nigel Jackett

Family	Species	Common name	Ridge N=62	Midridge N=23	Gully N=15	Total N=100
Chelidae	<i>Chelodina longicollis</i>	Long-necked Tortoise				†
Varanidae	<i>Varanus rosenbergi</i>	Heath Monitor	1			1
	<i>Varanus varius</i>	Lace Monitor	2		1	3
Gekkonidae	<i>Diplodactylus vittatus</i>	Stone Gecko	1			1
	<i>Oedura lesueurii</i>	Lesueur's Gecko	101		9	110
Pygopodidae	<i>Pygopus lepidopodus</i>	Scaly Foot				†
Agamidae	<i>Amphibolurus muricatus</i>	Jacky Dragon	6	3	1	10
	<i>Physignathus lesueurii howitti</i>	Gippsland Water Dragon	1		8	9
	<i>Tympanocryptis diemensis</i>	Mountain Dragon			1	1
Scincidae	<i>Bassiana platynota</i>	Red-throated Skink	22		2	24
	<i>Cryptoblepharus virgatus</i>	Wall Skink	34		3	37
	<i>Ctenotus robustus</i>	Striped Skink				g
	<i>Ctenotus taeniolatus</i>	Copper-tailed Skink	64	3	7	74
	<i>Cyclodomorphus michaeli</i>	She-oak Skink				†
	<i>Egernia cunninghami</i>	Sydney Cunningham Skink	14			14
	<i>Egernia saxatilis</i>	Black Rock Skink	2	1	2	5
	<i>Egernia whitii</i>	White's Skink				†
	<i>Eulamprus heatwolei</i>	Southern Water Skink	2	8	16	26
	<i>Eulamprus quoyii</i>	Eastern Water Skink	62	12	59	133
	<i>Eulamprus tenuis</i>	Barred-sided Skink	1	1		2
	<i>Lampropholis delicata</i>	Dark-flecked Sunskink	130	97	44	271
	<i>Lampropholis guichenoti</i>	Pale-flecked Sunskink	33	20	11	64
	<i>Nannoscincus maccoyi</i>	Maccoy's Skink			1	1
	<i>Pseudemoia spenceri</i>	Spencer's Skink		4		4
	<i>Saproscincus mustelinus</i>	Weasel Skink	8	1	1	10
	<i>Tiliqua nigrolutea</i>	Blotched Bluetongue				j
	<i>Tiliqua scincoides</i>	Common Bluetongue				†
Boidae	<i>Morelia spilota spilota</i>	Diamond Python	1			1
Elapidae	<i>Acanthophis antarcticus</i>	Death Adder				e
	<i>Austrelaps ramsayi</i>	Highland Copperhead				†

Family	Species	Common name	Ridge N=62	Midridge N=23	Gully N=15	Total N=100
Typhlopidae	<i>Cacophis squamulosus</i>	Golden Crown Snake				†
	<i>Demansia psammophis</i>	Yellow-faced Whip Snake	1			1
	<i>Drysdalia coronoides</i>	White-lipped Snake				α
	<i>Drysdalia rhodogaster</i>	Master's Snake	1			1
	<i>Hemiaspis signata</i>	Swamp Snake				†
	<i>Hoplocephalus bungaroides</i>	Broad-headed Snake	12			12
	<i>Notechis scutatus</i>	Tiger Snake				†
	<i>Pseudechis porphyriacus</i>	Red-bellied Black Snake	1	2		3
	<i>Pseudonaja textilis</i>	Eastern Brown Snake	1			1
	<i>Rhinoplocephalus nigrescens</i>	Small-eyed Snake	18			18
	<i>Ramphotyphlops nigrescens</i>	Black Blind Snake	†			†
		Total Species	24	11	15	41
		Total Individuals	519	152	166	837

Threatened and regionally significant species

Twelve *Hoplocephalus bungaroides* were found at seven ridge sites and a sloughed skin was found at another site. This species was the second most common snake detected during systematic surveys. *Hoplocephalus bungaroides* were found under loose sandstone that lay on the parent rock. Although *H. bungaroides* was detected under Nowra and Hawkesbury Sandstones the common features of refuge sites were that rocks were located on the edge of the escarpment at sites that had jutted out from the main escarpment and had a north to western aspect. The rocks were relatively flat and had a diameter which ranged from approximately 0.3-1.0 m. Rocks were in relatively exposed positions and had a neat fit with the parent rock. The firm juxtaposition of rocks and the location of micro-habitat in exposed positions were factors that excluded organic debris from being washed or blown under the rocks. The substrate under refuge rocks was dry. Ant nests were absent from rocks utilised by *H. bungaroides*. A

single *Rhinoplocephalus nigrescens* was found under the same rock as a *H. bungaroides*. Three juvenile *H. bungaroides* were found under one rock.

Cage trapping caught two *Varanus rosenbergi*, one at a ridge site and the other at a targeted site for that species (beside the burrow in mounded sand). One *Varanus rosenbergi* was also observed during systematic surveys on a ridge (Table 3) and another found as a road kill. All records were from sites that had exposed rock outcrops.

The vegetation associations at these sites where *Hoplocephalus bungaroides* and *Varanus rosenbergi* were found were ecotonal with tall forest below the escarpment and open forest/woodland behind the escarpment. The main associations were *E. punctata*, *E. piperita* and *Corymbia gummifera*. There was minor occurrence of Turpentine *Syncarpia glomulifera*, White Stringybark *E. globoidea* and *E. sclerophylla*. Tickbush *Kunzea ambigua* and Dagger-leaved *Hakea H. dactyloides* were often present in the understorey.

Table 4. Number of frogs detected during systematic surveys.
† = observed during targeted or opportunistic surveys but not during systematic surveys.

FAMILY	SPECIES	COMMON NAME	Total
Hylidae	<i>Litoria caerulea</i>	Green Tree Frog	†
	<i>Litoria citropa</i>	Blue Mountains Tree Frog	14
	<i>Litoria dentata</i>	Bleating Tree Frog	†
	<i>Litoria ewingii</i>	Ewing's Tree Frog	†
	<i>Litoria fallax</i>	Dwarf Tree Frog	1
	<i>Litoria freycineti</i>	Freycinet's Frog	†
	<i>Litoria jervisiensis</i>	Jervis Bay Tree Frog	1
	<i>Litoria lesueurii</i>	Lesueur's Frog	22
	<i>Litoria littlejohni</i>	Heath Frog	114
	<i>Litoria nudigita</i>	Leaf Green Tree Frog	94
	<i>Litoria peronii</i>	Peron's Tree Frog	2
	<i>Litoria tyleri</i>	Tyler's Tree Frog	†
	<i>Litoria verreauxii</i>	Verreaux's Tree Frog	1
	<i>Litoria wilcoxii</i> (?)		9
Myobatrachidae	<i>Crinia signifera</i>	Common Eastern Froglet	129
	<i>Heleioporus australiacus</i>	Giant Burrowing Frog	†
	<i>Paracrinia haswelli</i>	Haswell's Frog	94
	<i>Limnodynastes peronii</i>	Striped Marsh Frog	5
	<i>Limnodynastes dumerilii</i>	Pobblebonk	†
	<i>Limnodynastes tasmaniensis</i>	Spotted Grass Frog	†
	<i>Mixophyes balbus</i>	Southern Barred Frog	†
	<i>Pseudophryne bibronii</i>	Bibron's Toadlet	13
	<i>Uperoleia laevisgata</i>	Smooth Toadlet	†
	<i>Uperoleia tyleri</i>	Tyler's Toadlet	†
		Total Species	24
		Total Individuals	499

Heleioporus australiacus was only detected during systematic surveys by the presence of tadpoles at one site in Red Rocks NR. However, diurnal searches for tadpoles at other creeks located eight *H. australiacus* breeding sites. Non systematic surveys at these sites only detected two calling males. Breeding sites were patchy in distribution. Many sites contained what appeared to be suitable habitat but did not have tadpoles of *H. australiacus*.

One *Mixophyes balbus* breeding site was located by the presence of tadpoles. No *M. balbus* tadpoles or calling adults were found at this site during surveys in January 2000 and no tadpoles have been observed since that time.

Habitat characteristics of the *H. australiacus* and *M. balbus* sites have been described elsewhere (Daly, 1996, 1998).

Litoria littlejohni was the most common species of tree frog found, with a total of 123 animals detected at 15 sites. All sites were in heath/woodland. Breeding activity (amplecting pairs, spawn and/or recently hatched tadpoles) of *L. littlejohni* was observed at 11 sites in early September 2001. Three amplexed females were observed. Frogs were clustered in their distribution along creeks. Calling males were most frequently detected stationed on low vegetation, which overhung slow flowing pools. Clusters of eggs were observed under the water, attached to narrow sticks.

All sites where breeding activity occurred were in the upper laterals of second and third order creeks. Fish were generally absent from these sites with only one eel observed during spotlight surveys. The altitude of sites ranged from 130-690 m AHD (average 366 m AHD). The substrate of all these sites was Nowra Sandstone. Several males were heard calling beside an ephemeral creek opportunistically at one site where Hawkesbury Sandstone was present.

Litoria littlejohni sites contained relatively undisturbed vegetation, which included

heathland, woodland and tall open forest that was adjacent to heathland. The main canopy trees at sites were *E. sclerophylla* and *E. piperita*. Common plant species adjacent to most breeding sites were Heath Banksia *B. ericifolia*, *H. sericea*, *Melaleuca squarrosa* and *Leptospermum rotundifolium*.

Litoria caerulea was found in a restricted area below 100 m AHD within four kilometres of Bomaderry Creek NR. This species was uncommon and occurred in farmland and adjacent woodland (*E. sclerophylla*/*E. punctata*).

Other species that were rarely detected were *Pygopus lepidopodus* (two records), *Diplodactylus vittatus* (one record), *Tympanocryptis diemensis* (one record), *Ctenotus robustus* (one record), *Eulamprus tenuis* (two records), *Nannoscincus maccoyi* (one record), *Tiliqua nigrolutea* (two records), *Morelia spilota* (one record), *Acanthophis antarcticus* (one record), *Austrelaps ramsayi* (one record), *Demansia psammophis* (one record), *Drysdalia coronoides* (one record), *D. rhodogaster* (one record), *Pseudonaja textilis* (one record), *Litoria fallax* (one record), *Litoria freycineti* (two records), *Litoria jervisiensis* (one record), *Litoria peroni* (two records) and *L. verreauxii* (two records). The latter two species of frog have large populations in the adjoining Jervis Bay subregion (Daly, 2000).

Previous surveys within the study area

Jenkins (1987), Murphy (1997) and Murphy and Daly (1998) published qualitative accounts on geographical subsets of the region's herpetofauna. Jenkins (1987) described the herpetofauna of the Budawang and the southern portion of Morton NP and listed eight species of reptile and three species of frog that were not recorded during the current assessment. Species detected by Jenkins (1987) but not found during the current survey include *Christinus marmoratus*, *Lialis burtonis*, *Delma inornata*, *Pogona barbata*, *Bassiana duperreyi*, *Furina diadema*, *Suta spectabilis*, *Vermicella annulata*, *Litoria aurea*, *Litoria raniformis* and *Mixophyes fasciolatus*.

Figure 2. Amplexing pair of *Litoria fallax* from Kangaroo Valley.



Figure 3. Female *Varanus rosenbergi* from Morton National Park.



DISCUSSION

Species diversity and density

Ridgelines (heath and woodland ecotone) had the highest species diversity of reptiles. Other quantitative surveys of reptiles in temperate south-eastern Australia (NSW NPWS, 2000; Daly, 2004) have also found that ridge sites with rock outcrops have higher species diversity than gully and then midridge sites. The determined density and species diversity was comparable for these studies. In particular north to north-west facing aspects with an abundance of loose rock on exposed sandstone outcrops had the highest species diversity. This habitat allowed a higher degree of sunlight to reach the ground than gullies or midslopes. The amount of direct sunlight and the properties of rock to radiate stored heat and provide refuge sites were considered significant biophysical components for certain species of reptiles.

Secondary creek lines that flowed through woodland/heathland in sandstone areas had the highest species diversity of frog. This habitat allowed more sunlight to reach the ground (water) than gully sites where tall open forest occurred. Altitude was a factor in the species diversity of frogs with the distribution of *Litoria littlejohni* constrained to select sites above 130 metres.

Species assemblages & zoogeographic patterns

There are certain reptiles and frogs that when grouped can be considered zoogeographically as suites that reflect common associations with biophysical components. One group of saxicolous species was highly associated with sandstone/sandy substrates and heath-woodland vegetation in the region surveyed. The saxicolous species *Oedura lesueurii*, *Varanus rosenbergi*, *Bassiana platynota*, *Cryptoblepharus virgatus*, *Ctenopus taeniolatus*, *Egernia cunninghami* (Sydney Sandstone form see Swan et al. 2004), *Egernia whitii*, *Demansia psammophis*, *Hoplocephalus bungaroides*, *Ramphotyphlops nigrescens*, *Litoria citropa*, *Litoria littlejohni*,

Heleioporus australiacus (northern form) occurred on the plateau and escarpment areas and have their south-eastern limit either within or close to the distribution of Nowra Sandstone (Swan et al., 2004; Daly, unpubl. data).

Hawkesbury Sandstone abuts Nowra Sandstone in the north west of the study area near Bundanoon Creek (CALM Soil Landscape Series - Kiama and Moss Vale sheets). During this survey *Oedura lesueurii*, *Bassiana platynota*, *Cryptoblepharus virgatus*, *Ctenopus taeniolatus*, *Egernia cunninghami* (Sydney Sandstone form), *Hoplocephalus bungaroides*, *Litoria citropa* and *Litoria littlejohni* were detected on both Hawkesbury and Nowra Sandstones. Habitat corridors for these and presumably the other above-mentioned saxicolous species require areas where sandstone outcrops as surface rock. Such a corridor occurs north of the study area along the Illawarra escarpment to Royal National Park and the Avon/Cordeaux areas of Sydney Catchment Authority (Daly, unpubl. data). The occurrence of sandstone outcrops is particularly narrow around Macquarie Pass.

Large rivers and lack of contiguous rock outcrops can act as barriers to dispersal for some species of reptile and frog. The Shoalhaven River and Kangaroo River appear to have inhibited *Egernia cunninghami*, *E. whitii*, *L. freycineti*, *L. littlejohni*, *L. dumerilii* and *P. haswelli* from colonising similar habitat in the Cambewarra/Budgong area. The species could not colonise the area from the upper catchment (Barren Grounds NR) because the sandstone has been eroded and exists as small isolated outcrops (i.e. Red Rocks NR, Devils Glen NR and The Rodway NR).

Daly (2000) found that a break of ten kilometres in sandstone outcrops inhibited *Varanus rosenbergi*, *Egernia cunninghami*, *E. whitii*, *Ramphotyphlops nigrescens* and *Hoplocephalus bungaroides* from colonising similar habitat in the nearby Jervis Bay region. Assuming localised extinctions have not occurred, the current and previous studies indicate that historical biophysical barriers

have prevented colonisation of all suitable habitats.

The highland species were mainly found at elevated sites in the western portion of the study area. *Egernia saxatilis*, *Pseudemoia spenceri*, *Tiliqua nigrolutea*, *Austrelaps ramsayi* and *Drysdalia coronoides* have colonised the western portion of Area Three from the Southern Tablelands and occur in woodlands and open forests. *Limnodynastes tasmaniensis*, which does occur at low altitudes in other regions (i.e. in Sydney), also occurred in the far western portion of the study area. *Litoria littlejohni* was detected between 130 to 640 m (AHD). This species distribution is highly associated with upland heath/woodlands of the escarpment.

A previous study north of Morton NP environs was conducted in the Wollongong local government area by NSW NPWS (2002). This study used the same methods as the current investigation and based on a Bray-Curtis similarity matrix recognised six distinct assemblages of reptiles based on broad vegetation associations and moisture gradients. Three of those assemblages were common to the current study: open forests (midslopes); heaths and woodlands (saxicolous assemblage on ridge sites), and creeklines.

There were several differences in the findings between this study and the current one. The Three-toed Skink *Saiphos equalis* was detected in 84% of open forest sites whereas this species was not found in the current study. To date *Saiphos equalis* has only been detected on the coastal plain (Shoalhaven Heads and Comerong Island) and not in the foothills and escarpment land currently surveyed.

In the heaths and woodlands of the Wollongong area *C. taeniolatus*, *L. delicata*, *O. lesueurii*, *B. platynota* and *T. diemensis* (35% of sites) were the most common species. In the current survey the first four species were also some of the most common species detected but *E. quoyii* and *C. virgatus* were also common in Morton NP on ridge sites. *Tympanocryptis diemensis* was only detected

once during the current survey during systematic sampling and was only observed in a few locations at high altitude.

Range Extensions - Limits of Distribution

Ctenotus robustus and *Pseudemoia spenceri* had not previously been recorded in the study area (Jenkins, 1987; Murphy & Daly 1998; Daly, 2000). Based on the current work and unpublished accounts the following species have their south-eastern limit in New South Wales in the study area: *Diplodactylus vittatus*, *Oedura lesueurii*, *Varanus rosenbergi*, *Ctenotus robustus*, *Ctenotus taeniolatus*, *Egernia cunninghami* (Sydney form), *Cacophis squamulosus*, *Demansia psammiphis*, *Hoplocephalus bungaroides* and *Ramphotyphlops nigriscens*. With the exception of *Cacophis squamulosus* these species are highly associated with woodland and sandstone outcrops (Hawkesbury and Nowra formations) in the Sydney Basin.

No members of the family Colubridae were detected in the study area. Brown Tree Snake *Boiga irregularis* and Green Tree Snake *Dendrelaphis punctulatus* have been recorded from the Wollongong region (NSW NPWS, 2002). No Broad-tailed Gecko *Phyllurus platurus* or Thick-tailed Gecko were detected during the current survey. These species also occur in the Wollongong area (NSW NPWS, 2002). Within the Sydney bioregion the above four species are closely associated with sandstone outcrops (pers. obs.). The highland species *Pseudemoia spenceri*, *Tiliqua nigrolutea*, *Austrelaps ramsayi* and *Drysdalia coronoides* were not detected in the Wollongong study (NSW NPWS, 2002). Limits of distribution of herpetofauna may be also influenced by other constraints such as temperature regimes.

Litoria wilcoxii has recently been described (Donnellan & Mahony, 2004), and was found in one area of the Kangaroo River catchment. Donnellan and Mahony (2004) found no genetic exchange with *L. lesueurii* within the Hawkesbury-Nepean catchment but hybrids were found in the Murrumbidgee. The speci-

mens found in Kangaroo Valley were considered *L. wilcoxi* based on colouration (yellow spots in groin area). However, genetic analysis of this population is needed to exclude the possibility of introgression.

Litoria fallax was initially detected in 1994 in a few ponds in Kangaroo Valley. This population has since spread and is now distributed over a wide area of farmland. *Litoria fallax* is considered to have been translocated into sites on the south coast of NSW (Daly, 2000; Daly & Senior, 2003).

Limnodynastes dumerilii dumerilii was detected in Morton NP, south of the Shoalhaven River. Previous surveys to the east of Morton NP found animals with characteristics consistent with *L. dumerilii insularis* in the coastal area around Jervis Bay (Daly, 2000). These subspecies have distinct distributions in the region.

Significance of Area for Threatened Species

The escarpment and plateaus south of the Shoalhaven River are significant because they contain populations of five species listed on the Threatened Species Conservation Act (1995): *Varanus rosenbergi*, *Hoplocephalus bungaroides*, *Litoria littlejohni*, *Heleioporus australiacus* and *Mixophyes balbus*.

The habitat utilised by *Hoplocephalus bungaroides* was similar to that described by Webb and Shine (1998). *Hoplocephalus bungaroides* occurred primarily in the presence of *Eucalyptus punctata*, which is known to be one of the main tree species used for arboreal refuge (Webb & Shine, 1998). The gecko *Oedura lesueurii*, which is a major food item for *Hoplocephalus bungaroides* (Wells, 1981), was common at most sites. However, in the far south of the sandstone plateau area in Morton NP, *Oedura lesueurii* was not found and *E. punctata* was not located and yet *H. bungaroides* was present. *Hoplocephalus bungaroides* may use different trees as summer refuge sites and have a different diet in the south of the study area.

There have been two extensive surveys (NSW NPWS, 2002; Newell & Goldingay, 2005) for herpetofauna conducted to the north of the study area that targeted *H. bungaroides*. Another broad-scale study was conducted by Shine *et al.* (1998). Only two *Hoplocephalus bungaroides* were detected at 100 sites (100 hours search effort) by NPWS (NSW NPWS, 2002). Newell and Goldingay (2005) detected ten *H. bungaroides* over 236 sites. Shine *et al.* (1998) detected eleven *H. bungaroides* from 54.5 hours search effort, but within the Morton NP area they detected five snakes in just eight hours.

Only surveys conducted by NPWS (2002) utilised the same survey methods as the current survey, the other studies conducted targeted surveys along ridgelines. Newell and Goldingay (2005) conducted targeted surveys along ridgelines that were not time/area limited and Shine *et al.* (1998) conducted surveys along 30 metre long transects over various time intervals. Given the above results, Morton NP has a relatively high density of *H. bungaroides* with 12 animals detected over 100 hrs search effort during the current study. If ridge sites are analysed separately then the detection rate would be 12 animals from 62 hours (sites) search effort.

Varanus rosenbergi was detected at a number of sites along the sandstone escarpment. It occurs at low densities and requires considerable search effort and a range of survey technique to detect. In relatively undisturbed areas the species is wary of humans and in both the present study and NSW NPWS (2002) was not frequently detected during systematic surveys. Most detections were made during drive transects (active and road killed specimens). Targeted cage trapping may detect this species but the capture rate (1/172 trap days) indicates that this method also requires a significant effort.

The current survey detected a large population of *Litoria littlejohni* over a number of sites. All (15) sites were within conservation reserves. Lemckert (2004) reviewed the number of calling males detected from a

broad but non-systematic data set and found that in 38 of 47 (81%) of records, only four or fewer males were recorded. Similarly, during 17 nocturnal streamside searches in the Wolongong area only one *Litoria littlejohni* was detected (NSW NPWS, 2002). Current information indicates that Parma Creek NR, Jerawangla NR and a portion of Morton NP are strongholds for the species (Daly and Craven *in prep.*).

Mixophyes balbus was detected at a single site from 1994-1998 by the presence of tadpoles (Daly, 1998). There was a high fidelity to the breeding site. This species has not been detected at this site since 2000 and the population may no longer persist. One other population was known in the broader Illawarra region, but this may no longer persist (Gaia Research, 2006). This species has had a drastic population decline in southern NSW (Daly *et al.*, 2002).

Heleioporus australiacus had a patchy distribution, being detected by the presence of tadpoles in small sections of second order creeks on the escarpment that flowed over sandstone.

Other Species Recorded from Previous Surveys

Jenkins (1987) detected an additional eight species of reptile and three species of frog in the study area, which indicates that either there has been a decline in some species and or the other species are rare or have limited distributions.

The absence of *Litoria aurea* and *Litoria raniiformis* may be result of marked declines in these species (Osborne *et al.*, 1996; White & Pyke, 1996; Daly & Senior, 2003). Other species such as *Lialis burtonis*, *Christinus marmoratus*, *Mixophyes fasciolatus*, *Delma inornata*, *Pogona barbata*, *Bassiana duperreyi*, *Furina diadema*, *Suta spectabilis* and *Vermicella annulata* may have restricted distributions or occurred in low population densities and hence were not found during the current survey.

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COMMUNAL NESTING IN THE RED-THROATED SKINK, *BASSIANA PLATYNOTA*

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INTRODUCTION

Communal nesting, or the clustering of eggs of several conspecific females, is widespread in both lizards and snakes (reviewed in Graves & Duvall, 1995; Branch, 1998). In lizards communal nesting is known in several families, including the skinks (reviewed in Graves & Duvall, 1995; Couper & Schneider, 1995; Spawls *et al.*, 2002; Silverschmidt & Goodman, 2003; Dixon, 2003). Theoretical investigations into any adaptive significance of communal nesting are lacking (but see hypotheses offered in Graves & Duvall, 1995), presumably in part because we do not know its prevalence, which in turn is related to the difficulty in locating squamate eggs (e.g., Perry & Dmi'el, 1994). Herein I present the first two reported incidences of communal nesting in the Red-throated Skink, *Bassiana platynota*.

RESULTS AND DISCUSSION

On 14 February 1998 I discovered a group of 27 *B. platynota* eggs in a sunny rock outcrop in dry sclerophyll forest along the Hume Hwy, 81 km north of Goulburn, NSW. The eggs were under a large (20 kg, 0.3 m x 0.5 m x 0.1 m) rock in an excavated dirt cavity. Three of the eggs had hatched, and three were hatching upon discovery, confirming species identification. Red-throated Skinks are relatively common at the site (pers. obs.).

On 21 December 2002 I found a second communal nest of *B. platynota* eggs in a crack (roughly 8 cm wide) of a sunny, north-facing rock face at Cave Creek, in Kosciuszko National Park, NSW. The 14 *B. platynota* eggs were found together with 10 Garden Skink (*Lampropholis guichenoti*) eggs, and 8 Water Dragon (*Physignathus lesueurii*) eggs. It is likely that the Water Dragon nested first, as

some of the skink eggs were on top of the dragon eggs, and Water Dragons excavate and backfill a chamber in the substrate. I have found *L. guichenoti* and *L. delicata* eggs in Water Dragon nests previously in Canberra (unpubl. data), and it may be that the latter provides an easily accessible nest site for the skinks. The Water Dragon eggs were identifiable by size and shape, and three eggs each of the two different sizes of skink eggs were incubated until hatching to confirm species identification.

The typical clutch size for *B. platynota* ranges from 3-10 (Greer, 1982, 1989), indicating that both nests were communal, the first nest representing the efforts of 3-9 mothers and the second nest involving 2-5 mothers. In the case of the first nest, there were many rocks of similar size with similar solar exposure adjacent to the nesting rock, indicating that this communal nest was apparently not an artefact of limited nest sites. Furthermore, even if the nesting rock was unique, other unused areas under the rock would presumably possess effectively identical incubation conditions (temperature and moisture). The second nest site was in a rock face, and substrate was limited to soil in cracks. However, eggs were spatially clumped, as further searching revealed no others eggs in several meters of crack with seemingly identical moisture and solar exposure (and thus, temperature).

Although not reported previously for *B. platynota*, communal nesting is common in several sympatric skinks, including the congeneric *Bassiana duperreyi* (Shine, 1983), *Lampropholis guichenoti* (Wells, 1981), *L. delicata* (Wells, 1981; Shea & Sadlier, 2000), *Saproscincus mustelinus* (Shea & Sadlier, 2000), and in several other skink species (Graves & Duvall, 1995). However, the extent of communal nesting in skinks is unknown.

Further observations of nests are needed to determine the prevalence of communal nesting in skinks, other lizards, and snakes. These reports will help clarify why so many reptiles nest communally.

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COURTSHIP AND COPULATION IN THE SOUTHERN WATER SKINK, *EULAMPRUS HEATWOLEI*

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At 1300 hr on 30 October 2003, in cool (approximately 10°C) but sunny weather, we observed courtship, copulation and mate defence in Southern Water Skinks (*Eulamprus heatwolei*). We were conducting fieldwork in the Brindabella Range near Canberra and had stopped for lunch at the Bulls Head survival shelter on Mt Franklin Road, in Namadgi National Park (35°23'16"S 148°48'13"E). Previous roadwork involving grading and repositioning of large logs had created a deep ditch between logs along the roadside. A wooden bridge had been put in place over the ditch to help picnickers reach the shelter safely, and as we were unloading the car, we noticed several *Eulamprus heatwolei* scurrying under the bridge and along the ditch.

A closer inspection of the ditch seconds later revealed the act of copulation taking place. The larger male had taken hold of the smaller female by biting her on the left flank, just below her left forelimb. His body was curled around above the female's, with his tail positioned up and under her tail, allowing intromission of his left hemipene (Fig. 1). Copulation lasted several minutes before they separated. The female then ran off along the ditch, with the male in hot pursuit, following her closely in and over the logs. Another smaller male then appeared, and advanced towards the female. The larger male promptly chased him off. The smaller male stopped a short distance away (approximately 1 m) and there followed much head-bobbing between the two males. Again, the larger male charged towards the intruding male, which scurried away and disappeared into a log. The larger male then returned to "his" female at which time there commenced a head-bobbing display between the male and female. This display lasted several seconds before they settled down into a basking

posture on the wooden bridge approximately 30 cm apart from each other.

While there has been considerable research on closely-related sister species (*Eulamprus quoyii*, *E. tympanum*: e.g. Schwarzkopf & Shine, 1991; Schwarzkopf, 1993, 1996; Blomberg, 1994; Doughty & Shine, 1997, 1998), there have been relatively few studies of *E. heatwolei*. Indeed, ours may be the first published description of copulation in *Eulamprus* spp. in general. Although recent work by Head *et al.* (2005) investigated courtship and sexual receptivity in *E. heatwolei*, this work was conducted under laboratory conditions. Head *et al.*'s (2005) data show that female *E. heatwolei* are only receptive for approximately 7 days in late October (in the laboratory). Our observation of courtship and copulation in free-ranging lizards on 30 October is consistent with their laboratory findings.

Additionally, our observation of the larger (resident?) male chasing the smaller (floater?) male from the vicinity of "his" female suggests mate defence in this species. A recent study by Morrison *et al.* (2005) used molecular techniques to determine paternity in a natural population of *E. heatwolei*, and suggested that this species has a multiple mating polygynous mating system. They also observed males chasing other males and sub-adults in close proximity, as well as male-male combat bouts in the field. However, Morrison *et al.* (2005) did not report mate-guarding in *E. heatwolei*. Morrison *et al.* (2005) found that a single male can overlap several female home ranges, but also that there is multiple paternity in litters. If a female is only receptive for a short time, it might make sense for a male to guard his harem of females to ensure paternity. However, the multiple paternity documented by Morrison *et al.* (2005) suggests that the floater males may get their chance

while the territory holders are away visiting other female home ranges. The extremely short period of female receptivity in this species (Head *et al.*, 2005), and our observation of the larger male defending "his" female against a rival male, suggest that the possibility of mate guarding warrants further research in this species.

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Figure 1. Copulation in a pair of southern water skinks.



CLUTCH TRAITS IN THE SKINK *CARLIA VIVAX*

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ABSTRACT

Clutch traits were collected from a sample of the invariant-clutch skink, *Carlia vivax*. In general, relative clutch masses were lower than reported for variant-clutch species, but similar to those of other invariant-clutch species (e.g., gekkonid and *Anolis* lizards), with both egg and offspring size relatively large for a lizard this size. These data suggest that some *C. vivax* produce clutches during the wet-season in tropical north-eastern Australia.

INTRODUCTION

Squamate reptiles exhibit a broad range of reproductive traits and strategies (Dunham *et al.*, 1988; Rohr, 1997), with considerable differences noted between tropical and temperate zone species (James & Shine, 1985, 1988; Shine & Greer, 1991). One life history trait that differs substantially between these two climatic zones is the proportion of species that produce an invariant or "fixed" clutch size (i.e., one or two egg clutches; James & Shine, 1988). Indeed, while the production of an invariant-clutch is well known for members of the lizard families Anolidae and Gekkonidae (Andrews & Rand, 1974; Kluge, 1987), it has often been less well documented for members of the Scincidae. This omission is noteworthy, as the production of an invariant-clutch size is not phylogenetically determined for members of this family (Fitch, 1970). This paper provides data on clutch traits of the tropical-sub-tropical skink, *Carlia vivax*.

MATERIALS AND METHODS

Carlia vivax is a small-medium (to 50 mm snout-vent length, SVL) diurnally active terres-

trial lygosomine scincid restricted to dry-open forests in eastern Queensland, Australia (Ingram & Covacevich, 1989; Cogger, 2000). Like other members of the genus *Carlia*, *C. vivax* presumably reproduces during the wet-season (Nov-Feb; James & Shine, 1985; Clerke & Alford, 1993) in tropical north-eastern Australia.

During 24-28 January, 2000, four gravid *C. vivax* were collected from a site 9 km west of Chillagoe (17°06'S 144°32'E) in north-east Queensland and transported to a laboratory at James Cook University, Cairns. Females were maintained separately in plastic containers (350 x 130 x 100 mm) with a moist potting mix substrate (to a depth of 10 mm), a bark refuge and a water bowl. Each box was placed on a heating rack with a heating wire positioned under one end that produced a thermal gradient (23–45°C) within each box from 0900 to 1800 hr that enabled thermoregulation. Outside these times the temperature dropped to 23°C ± 2°C. The local photoperiod was mimicked using standard overhead fluorescent lights. Lizards were fed two medium sized mealworms or crickets two-three times weekly; water was always available.

The following data were recorded when a female had oviposited: female mass (± 0.01 g), SVL (± 0.01 mm), egg mass (± 0.001 g), egg width and egg-length (± 0.1 mm). Egg volume was calculated using the formula for a prolate spheroid $\frac{4}{3}\pi ab^2$, where a = half the diameter of the longest egg dimension, and b = half the diameter of the shortest egg dimension (Mayhew, 1963). Relative Clutch Mass (RCM) was defined as the total mass of the clutch divided by maternal post-partum mass (Shine, 1980). Each egg was placed separately in a 100 mL plastic jar containing

moist vermiculite (-200 kPa water potential) and covered with plastic cling wrap to prevent water loss and incubated at $25 \pm 2^\circ\text{C}$. For each hatchling, body weight (± 0.001 g) and SVL and tail length (± 0.1 mm) were recorded. Following this all individuals were released at the collection site.

RESULTS

All gravid *Carlia vivax* oviposited within four weeks of capture (oviposition dates: 06.ii.2000, 07.ii.2000, 10.ii.2000, 23.ii.2000) and produced clutches consisting of two eggs. In near-term individuals eggs occupied much of the available space in the abdominal cavity, with both eggs positioned in a slightly offset medial position, with one egg positioned slightly more anterior than the other. The smallest individual that produced a clutch had a SVL of 44.7 mm. Table 1 presents descriptive statistics for reproductive parameters of *C. vivax*. Small sample sizes precluded an investigation of maternal size-egg size relationships. A single egg laid 10.ii.2000 hatched 40 days later. This hatchling had a SVL = 18.88 mm, mass = 0.163

g, tail length = 28.5 mm. This hatchling represents 41 % of maternal SVL or 9.6 % of maternal mass.

DISCUSSION

The four *C. vivax* produced clutches of two eggs, which is consistent with published reports of other *Carlia* species (Wilhoft, 1963; James & Shine, 1988; Clerke & Alford, 1993). As these individuals were all sampled in January and oviposited in February, this suggests that reproductive seasonality in *C. vivax* is confined to the wet-season (November-February) in tropical north-eastern Australia. However, while these data are suggestive and support published accounts of reproductive seasonality in other *Carlia* species from this region (Clerke & Alford, 1993), additional data are required to conclusively test this notion.

The effective amount of space available for eggs is likely to be lower in taxa with small clutches of large eggs (Ebert, 1994; Charnov *et al.*, 1995), such that egg positioning in species such as *C. vivax* is presumed to be particularly important. For instance, a clutch

Table 1. Reproductive traits of four female *Carlia vivax* from Chillagoe, north-east Queensland.

Trait	Mean \pm SE
Clutch size	2
Snout-vent length (mm)	46.1 \pm 0.746
Post-oviposition mass (g)	1.7 \pm 0.11
Egg Volume (mm ³)	305.0 \pm 7.29
Egg Mass (g)	0.20 \pm 0.020
Clutch mass (g)	0.39 \pm 0.040
Egg Length (mm)	10.1 \pm 0.19
Egg Width (mm)	5.8 \pm 0.26
Relative Clutch Mass	0.23 \pm 0.036

of a few large eggs is more difficult to accommodate in a given volume than a larger clutch of small eggs. In near-term gravid *C. vivax*, eggs were generally positioned in a slightly offset medial position, which presumably maximizes the amount of available space for the eggs. Egg positioning is generally acknowledged as the most effective use of available volume, while maintaining sufficient locomotor and lung function (Miles *et al.*, 2000; Qualls & Shine, 1998; Schwarzkopf, 1994); whether this is the case for diurnal invariant-clutch species is unknown.

Carlia vivax exhibited a low RCM (Table 1) which was generally lower than that of variant-clutch taxa (e.g., other scincids, 0.380-0.541; Dunham *et al.*, 1988). This RCM was similar to that for other invariant-clutch two-egg producing species (e.g. geckos, 0.214-0.39; Skinks, 0.29; Greer, 1989; Doughty & Shine, 1995; Doughty, 1996, 1997; Doughty & Thompson, 1998). These data, while few may be suggestive that invariant-clutch species produce lower RCMs than variant-clutch species. However, while a reduction in RCM following a reduction in clutch size may seem intuitive (e.g., Vitt, 1981), we need additional data from a greater range of invariant-clutch species. For example, in geckos of the *Gehyra variegata-punctata* group, a shift from the larger ancestral body size to a smaller body size was accompanied by a shift from two to one-egg clutches, and an increase in egg volume, and relative clutch mass (Doughty, 1996), indicating that a simple reduction in clutch size may not necessarily lead to a reduction in RCM.

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A RANGE EXTENSION FOR THE ASIAN HOUSE GECKO *HEMIDACTYLUS FRENATUS*: A RECORD FROM COFFS HARBOUR, NEW SOUTH WALES

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The Asian House Gecko *Hemidactylus frenatus* is probably an accidental introduction to Australia (Cogger, 1996) and until recently was known to be established in urban areas along the east coast of Australia from Torres Strait to Murwillumbah, NSW (Wilson & Swan, 2003). During the period from December 2003 to January 2004 four specimens were collected (Queensland Museum J 80550-53) at Broken Head, NSW (28°42'S 153°35'E), just south of Murwillumbah.

In presenting the following records, the author wishes to draw attention to this species now becoming established approximately 180 kilometres further south along the east coast of NSW.

On 23 March, 2005 an electrician was working on a fluorescent security light at the Zebra Motel in Coffs Harbour, NSW (30.31319°S 153.13753°E). While he was removing the cover from the light fitting, six calcareous-shelled eggs were accidentally dropped onto the concrete floor from a height of approximately 2 m. Only one egg survived the fall and to confirm the origins of this egg it was taken away for incubation and maintained at 30°C. The temperatures inside the light fitting were recorded as 19°C at the coolest point in the light and 45°C at the warmest section, next to the ballast, with an ambient temperature of 15°C. These lights were left on 24 hours per day.

The owner of the Zebra Motel was made aware of the possibility that these eggs were from the Asian House Gecko as he claimed to have heard the distinctive "chk-chk-chk" call around the motel on occasions. On 7 April, 2005 a gecko was captured in one of the rooms of the Zebra Motel (Figure 1). It was

identified as an adult female *H. frenatus* (SVL 50 mm, total length 96 mm).

On 20 April, 2005 from the single egg hatched a *H. frenatus* (SVL 21 mm total length 41.5 mm). This indicated that *H. frenatus* was established at the Zebra Motel in Coffs Harbour and that the egg came from a communal nesting site (Cogger, 1996).

The adult was offered small mealworms and the hatchling was offered small cockroaches. They both fed on the same days and the lowest temperature recorded when feeding was 15.8°C on 18 May, 2005.

After recording these low feeding temperatures, the author believes that there is little stopping these geckos becoming established even further south than Coffs Harbour, particularly as they do not shun bright light (Bustard, 1970) and can feed on insects attracted to the lights that provide enough warmth for them and their nesting sites.

ACKNOWLEDGMENTS

The specimens were collected under NPWS Permit S11322. Thank you to the Peter Rankin Trust Fund for Herpetology for providing funding for the project titled 'The distribution and abundance of reptiles on the mid north coast of New South Wales', Steve McEwan for providing the photographs and data, Dr Andrew Amey for providing locality information for the *H. frenatus* specimens within the Queensland Museum and the owner of The Zebra Motel in Coffs Harbour for bringing this to our attention.

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Figure 1. The adult female *Hemidactylus frenatus* captured at Coffs Harbour.



Figure 2. The right rear foot of the *Hemidactylus frenatus* captured at Coffs Harbour.



CAPTIVE REPRODUCTION AND JUVENILE GROWTH RATES IN THE LAND MULLET (*EGERNIA MAJOR*)

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INTRODUCTION

The Land Mullet (*Egernia major*) is a large, diurnal skink species, attaining a snout-vent length of 30 cm and a total length in excess of 60 cm. It inhabits regions of rainforest and associated wet sclerophyll forest in south-eastern Australia. This secretive species largely occupies areas with thick vegetation, often sheltering within fallen hollow logs (Klingensböck *et al.*, 2000).

Species from the genus *Egernia* are often kept in captivity due to their robust size and social behaviour. Captive reproduction has previously been documented in a number of *Egernia* species (Banks, 1986; Post, 2000; Manning, 2002). In this paper, the husbandry and captive reproduction of *E. major* at Taronga Zoo, Sydney, is described, including notes on juvenile growth rates and a congenital birth defect.

HUSBANDRY

Three adult *E. major*, one female (SVL = 295 mm, mass = 936 g) and two males (SVL = 291 mm, mass = 786 g; SVL = 297 mm, mass = 873 g), are maintained in an outdoor exhibit situated at Serpentina in Taronga Zoo, Sydney. All three individuals arrived as adults from a captive collection in June 1995, with their prior history and age unknown. Their enclosure is roughly semi-circular in shape with a total ground area of approximately 20 m². The rear of the enclosure is equipped with a large artificial rock outcrop, whilst at the front of the enclosure exists the stump of a Eucalypt, a large Spiny-headed mat-rush *Lomandra longifolia*, a Hairpin Banksia *Banksia spinulosa* and a large log laid down over the substrate. The substrate consists of kikuyu grass, pine needles and leaves.

As the exhibit is located outdoors, it permits natural sunlight and weather, thus experiencing natural Sydney temperatures throughout the year. Artificial heating is also supplied by three 300 watt spotlights situated 1.1, 1.4 and 1.7 metres above the rock outcrop and two artificial heat rocks, providing temperatures of between 33°C and 43°C. The enclosure in which the *E. major* are contained is a mixed-species exhibit, also housing one adult Cunningham's Skink (*Egernia cunninghami*), six adult Blue-tongued Lizards (*Tiliqua scincoides*) and five juvenile Eastern Bearded Dragons (*Pogona barbata*).

The lizards are fed a mix of finely chopped fruits and vegetables, soaked dog kibble and non-fish varieties of tinned cat food three times per week between the months of September and April. Lizards also have access to locally occurring insects that enter the enclosure naturally and calcium-dusted crickets, which are scattered throughout the enclosure three times per week. Fresh water is always available in an artificially constructed pond and the enclosure is spot cleaned daily to remove faecal material and fallen leaves.

Reproduction

Captive reproduction of *E. major* has occurred on five occasions at Taronga Zoo since 1984 from various parents. Litter size has varied from 2 to 8 offspring (mean = 4), which concurs with previous records of reproductive output for this species being between 2 and 9 young (Swan, 1990). The current group of three adult *E. major* have been housed together since June 1995 without separation throughout the year. One previous record of reproduction from this group occurred on 13 January 1999, with the birth of three offspring. On 31 December 2003, eight neonate *E. major* were located within

the enclosure. No mating was observed so the sire of the offspring could not be determined. The average snout-vent length of neonates was 82.4 mm (min = 80 mm, max = 85 mm), whilst the average total length was 178.6 mm (min = 172 mm, max = 185 mm). The average mass of neonates was 17.0 g (min = 12.2 g, max = 18.7 g).

Two of the eight neonates were born with a congenital birth deformity. On both individuals, the right side of the upper and lower jaws were partly fused, greatly restricting the gape of the animal. On one individual the length from the tip of the snout to the corner of the mouth on the right side of the jaw was only 42% of that on the left side. The other individual was affected to a lesser extent, with the right side of the jaw extending to 73% of that on the left side. None of the adult *E. major* display any asymmetry of the jaws and no defects were noted in a previous litter. Congenital birth defects have previously been documented in *Egernia* sp, with a slight spinal twist and malformed rear legs being reported in Cunningham's Skinks (*E. cunninghami*) and missing toes and a foot in a Hosmer's Skink (*E. hosmeri*) (Banks, 1986).

Juvenile Husbandry and Development

Immediately after the neonates were discovered, they were transferred into off-exhibit indoor enclosures. Seven of the neonates were placed into an enclosure measuring 120 cm (length) x 90 cm (width) x 48 cm (height). This enclosure had a substrate consisting of leaf litter above soil. Large pieces of bark were provided for shelter. The rear half of the enclosure was heated with an under-floor heat mat and a 300 W UV spotlight was situated above the rear corner of the enclosure, providing a heat gradient throughout the cage from 35°C under the basking light to 24°C in the opposite corner. The neonate with the most expressed jaw deformity was separated and placed in a single enclosure to ensure it was able to feed. This enclosure measured 59 cm x 56 cm x 43 cm, also with a heat mat under the rear half of the enclosure, but with fluorescent tubes overhead. The

substrate within this enclosure was newspaper, with pieces of bark provided for shelter. All neonates were fed the same diet as adults, but more finely-chopped, three times a week throughout the year. Calcium-dusted crickets were also fed to neonates twice a week all year round.

The growth and weights of all juvenile Land Mulletts were measured on a monthly basis over a twelve month period. Mass was measured to an accuracy of 0.1 g using an AND digital scale and snout-vent length was measured to the closest millimetre with Kinchrome vernier callipers. The lizards grew at a relatively steady rate over the twelve months, almost doubling in length and reaching over four times their birth mass (Figure 1 and 2). There was a reduction in growth between the cooler months of June and August. The growth rates shown here in *E. major* are similar to those demonstrated in other species of *Egernia* (Banks, 1986).

Although feeding readily, the two individuals with partly fused jaws grew at a much slower rate than the other juveniles. The juvenile with the most deformed jaw, although feeding quite well, was not able to significantly increase in mass throughout the year. As food intake for the juveniles was not measured, it could not be determined if this was due to an inability to consume large amounts of food or due to the animal being stunted by its deformity. However, as this lizard was housed individually, it could be established that reduced growth rates were not attributed to stress caused by more dominant larger siblings.

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Figure 1. Growth in snout-vent length of juvenile Land Mullets until 12 months of age, comparing the average (\pm standard error) growth rates of the six healthy young (\blacklozenge) to that of the individuals with a lesser and greater extent of jaw deformity (\blacktriangle and \blacksquare respectively).

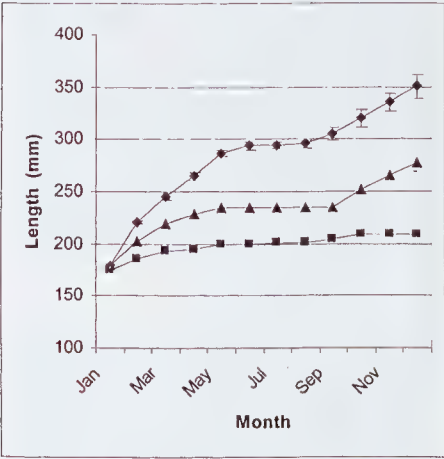
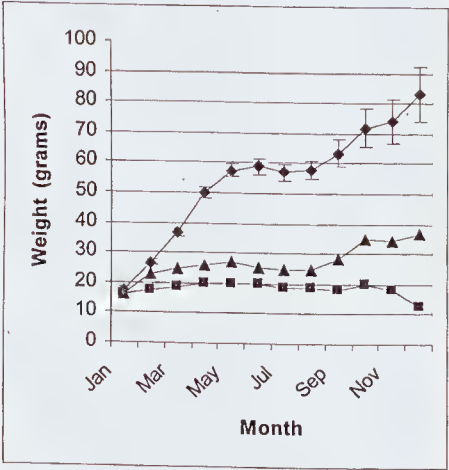


Figure 2. Increase in mass of juvenile Land Mullets until 12 months of age, comparing the average (\pm standard error) growth rates of the six healthy young (\blacklozenge) to that of the individuals with a lesser and greater extent of jaw deformity (\blacktriangle and \blacksquare respectively).



SPAWNING BEHAVIOUR OF THE RED-EYED TREEFROG *LITORIA CHLORIS* (ANURA: HYLIDAE)

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The spawning behaviour of most Australian frog species, including many common species, has not been described. Here, for the first time, I describe the spawning behaviour of the Red-eyed Tree Frog (*Litoria chloris*) from eastern Australia.

Breeding Red-eyed Tree Frogs (*L. chloris*) were observed in a shallow ornamental pond at O'Reilly's Guesthouse, Green Mountains, in south-east Queensland (28°13'50"S 153°08'02"E) from 4 December through to 8 December, 2004. During this time Green Mountains receives in excess of 150 mm of rain with daytime temperatures remaining low (below 22°C). Air and water temperatures recorded when observations were made (at dusk, by night and at sunrise) ranged from 15 to 18.5°C and 15 to 16°C respectively.

Male *L. chloris* first began calling on dusk following afternoon showers on 4 December. A single amplexant pair was seen later that night (ca. 2230 hr), but no spawn was found the following morning. *Litoria chloris* were again heard calling on the evening of 6 December following afternoon showers. At 2230 hr, several pairs were seen in amplexus around the study pond, but spawning had still not taken place. While spawning was not observed, a small amount of *L. chloris* spawn (several hundred floating eggs) was found the next morning.

On the evening of 7 December, *L. chloris* began calling on dusk again. Several amplexant pairs were observed later that evening (ca. 2230 hr) but spawning was not observed until the following morning. At 0700 hr on the morning of 8 December, three amplexant pairs were observed spawning in water with several others sheltering under rocks nearby. The description which follows is based on direct observation and photographs

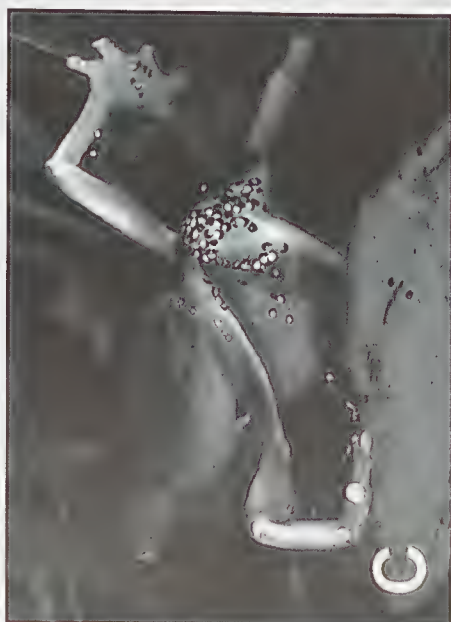
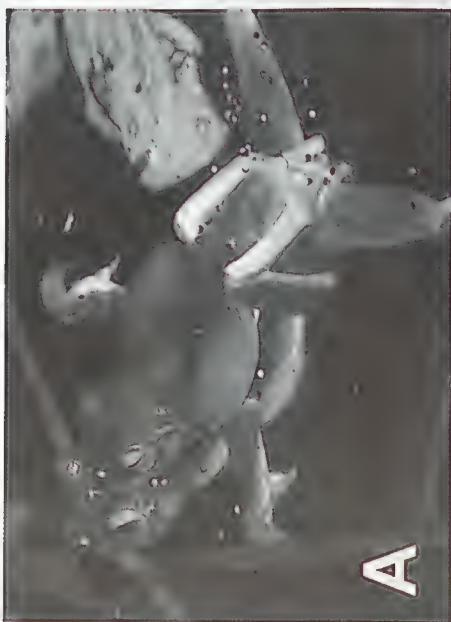
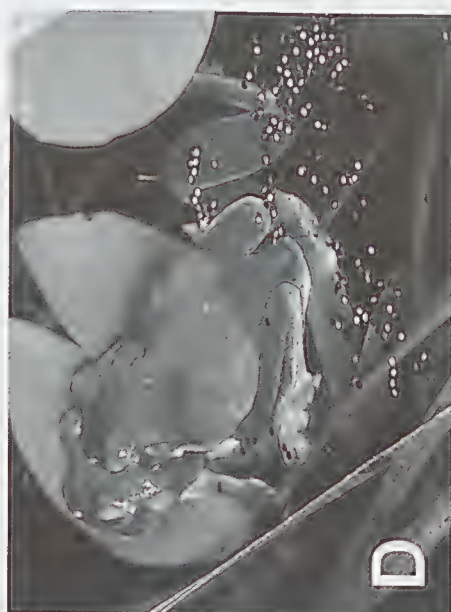
taken of spawning animals at this time.

Prior to oviposition, whilst in axillary amplexus, female *L. chloris* adopt a 'spread-eagle' position with legs and arms outstretched (Figure 1). At this point, amplexant males swing their legs back bringing their feet together behind them. With toes intertwined, males hold their feet tightly against their own vent and that of the female, occluding both male and female vents (Figure 1A). Amplexant female *L. chloris* then bring their vent out of the water (Figure 1B), after which males pull themselves forward and part their feet, allowing fertilised eggs to slide into the water below (Figure 1C). Having shed between thirty and fifty eggs, the female lowers her vent into the water (Figure 1D), kicks once, and the entire process is repeated again, three or four times in rapid succession. Amplexant pairs then rest for 5-10 minutes before resuming egg-laying.

Over the time which animals were observed spawning (approximately 45 minutes) each pair laid between 500 and 1000 eggs (a third to two-thirds the maximum number reported for *L. chloris* by Anstis [2002]). The total numbers of eggs laid could, however, have been greater as animals may have begun spawning well before observations began at 0700 hr.

The spawning behaviour of *L. chloris* described here differs markedly from that reported for other *Litoria* species to date. For those *Litoria* species in which spawning has been described, fertilization occurs in water after eggs have been shed from the female vent (Anstis, 1976; 2002; Anstis & Littlejohn, 1996). In *L. chloris*, however, sperm and eggs are prevented from spilling out into the surrounding water by the amplexant male, whose feet occlude his vent and that of the

Figure 1. Spawning in *L. chloris*: (A) male *L. chloris* with feet held up against its own vent and that of the female below it; (B) a female *L. chloris* in amplexus lifting its vent out of the water; (C) a male *L. chloris* moves forward pulling his feet apart, allowing fertilised eggs to fall into the water below; (D) male and female *L. chloris* at rest immediately after spawning.



female. Mixing of sperm and ova would appear to occur out of water when the female raises her vent upwards, with fertilised eggs reaching the water only after the male has parted his feet.

While newly reported in *Litoria* species, similar behaviour has been observed in other frog species including *Ptychadena* spp. and *Pyxicephalus* spp. from Africa. In these species, eggs and sperm are released synchronously out of water, possibly as a means of increasing fertilisation success (Passmore & Carruthers, 1995). Males of *Ptychadena* and *Pyxicephalus* species, however, do not hold their feet in apposition to the female vent. To date, such behaviour has only been reported for *L. chloris*.

Another unusual feature of spawning observed in *L. chloris* is the delay in oviposition after the onset of amplexus. Given the ease with which animals could be observed and photographed spawning, this delay is unlikely to be attributable to the presence of onlookers. Overnight showers and rain could instead have inhibited spawning, with females choosing to delay oviposition in order to maximise fertilisation success (since eggs are fertilised out of water). It is also possible, however, that the observed delay in

spawning is simply attributable to endogenous factors, having nothing to do with rain or the presence of onlookers. Further observations of spawning in *L. chloris* are needed to determine whether or not this is the case and to ascertain whether the behaviour described here is in fact typical for *L. chloris*.

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A NOTE ON THE DIET OF THE STRIPED MARSH FROG *LIMNODYNASTES PERONII* IN THE SYDNEY BASIN BIOREGION

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The Striped Marsh Frog, *Limnodynastes peronii*, is one of the most commonly encountered frogs in eastern Australia (Robinson, 1998). It is a medium to large myobatrachid frog (SVL = 60 cm) that is found along the coast in mainland Australia, from Queensland to Victoria and also in Tasmania (Cogger, 2000). Although a large number of frog species worldwide are undergoing declines, anecdotal reports indicate that populations of *L. peronii* have appeared to remain stable and may have increased in recent times.

Despite the broad distribution and relatively high abundance of this species, little is known about its ecology, including its diet. While there are a number of anecdotal reports on the diet of *L. peronii*, there is only one published record (Rose, 1974). This describes the stomach contents of seven road killed specimens collected at Ku-ring-gai Chase National Park. We examined the diet of *L. peronii* at two sites in the Sydney Basin Bioregion.

The diet of *L. peronii* was examined using stomach flushing (Legler & Sullivan, 1979). The number of whole prey items flushed from each stomach were counted and then identified to the level of order, except for those belonging to Gastropoda and Diplopoda, which were only classified to class due to difficulties with identification. Hereafter all specimens identified to order, or class for Gastropoda and Diplopoda are referred to as prey groups. Any prey items that had decomposed into two or more pieces were excluded from the results. On the 2nd and 3rd of February 2000, the diet of eight *L. peronii* (six males; two females) was examined at North Avoca, NSW (33°27'S 151°25'E). Avoca Swamp is reported to be an artificial swamp that was created in the 1970s

(Pyke, personal communication). It is approximately 200 m in circumference and is surrounded by a *Casuarina* woodland. On the 10th and 24th February 2000, the diet of 32 *Limnodynastes peronii* (23 males; 8 females; 1 unknown) was assessed at Long Reef Golf Course (33°51'S 151°10'E). The four ponds surveyed at Long Reef Golf Course were artificially created and vary in size from 20 m to 170 m at the greatest circumference. The four ponds vary in vegetation density and composition, but are all surrounded by Kikuyu (*Penisetum clandestinum*).

Food was not recovered from all frogs at both sites. Only 50% of *L. peronii* captured at North Avoca contained prey items and 62.5% at Longreef Golf Course. Of the frogs that contained food, the mean number of prey items per stomach was similar at North Avoca (mean = 2.4 ± 0.5) and Longreef Golf Course (mean = 2.2 ± 0.3).

A summary of the prey identified is presented in Table 1. Diets of *L. peronii* were similar at both sites with Hymenoptera being the most commonly observed prey group. Prey items from a total of eleven groups were observed during this study. Nine prey groups were retrieved from *L. peronii* stomachs at Longreef Golf Course and seven from North Avoca. While there was considerable overlap between the two sites, four prey groups (Orthoptera, Gastropoda, Lepidoptera and Haplotaenidia) were unique to Longreef Golf Course and two (Mantodea and Amphipoda) were unique to North Avoca. Given the small sample sizes it is possible that some of these prey groups were missed.

This study found that *L. peronii* has a seemingly broad diet consisting primarily of terrestrial invertebrates, but also included some

aerial invertebrates. This is consistent with the findings of Rose (1974) who recorded that the diet of *L. peronii* consisted of Coleoptera, Hemiptera, Formicidae, Araneae and Lepidoptera. Other studies on myobatrachid diet have also shown that prey items are predominantly terrestrial (Pengilley, 1971; Webb, 1983, 1987).

While some myobatrachid species reportedly have a broad diet i.e. *Heleioporus australiacus*, *Uperoleia* sp. and *Crinia signifiera* (Pengilley, 1971; Webb, 1983, 1987), others exhibit a narrow diet i.e. *Pseudophryne bibroni*, *Pseudophryne corroboree* and *Pseudophryne dendyi*, which feed predominantly on Formicidae and Isoptera (Pengilley, 1971). It is not clear whether *L. peronii* exhibits a dietary preference or if the consumed items simply reflect the relative abundances of available prey at the two study sites. This is an area that requires further research and may account for the success of *L. peronii* throughout its range.

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Table 1. Summary of prey identified for *L. peronii* at Longreef Golf Course and North Avoca.

Prey Type	Number and % of prey items at Longreef Golf Course		Number and % of prey items at North Avoca	
Hymenoptera	17	(39.5%)	5	(41.7%)
Coleoptera	8	(18.6%)	1	(8.3%)
Diplopoda	4	(9.3%)	1	(8.3%)
Acarina	4	(9.3%)	2	(16.7%)
Araenae	3	(7.0%)	1	(8.3%)
Orthoptera	2	(4.7%)	0	(0.0%)
Gastropoda	2	(4.7%)	0	(0.0%)
Lepidoptera	2	(4.7%)	0	(0.0%)
Haplotoxida	1	(2.3%)	0	(0.0%)
Mantodea	0	(0.0%)	1	(8.3%)
Amphipoda	0	(0.0%)	1	(8.3%)

NATURAL HISTORY NOTES ON THE WHITE-THROATED SNAPPING TURTLE, *ELSEYA* SP., FROM THE JOHNSTONE RIVER, NORTH QUEENSLAND

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INTRODUCTION

The existence of several undescribed taxa of the *Elseya dentata* complex from coastal Queensland has been known for some time (Goode, 1967: 54-55; Cann, 1978: 61, 1998: 193; Georges & Adams, 1992, 1996; Georges, 1993) and recently two of these have been formally described (Cann, 1997; Thomson *et al.*, 2006). The three recognized forms are allopatric, occupying separate drainages: the Johnstone *Elseya* sp., Burdekin *E. irwini* and the Burnett, Mary and Fitzroy-Dawson *Elseya* sp. nov. All three forms are morphologically similar but distinguishable (Cann, 1998: 189-190; Thomson, 1998; Thompson *et al.*, 2006) and biochemical evidence indicates the Johnstone and Burnett forms are very closely related, although comparisons with *E. irwini* are not fully resolved (Georges & Adams, 1992, 1996; Thompson *et al.*, 2006).

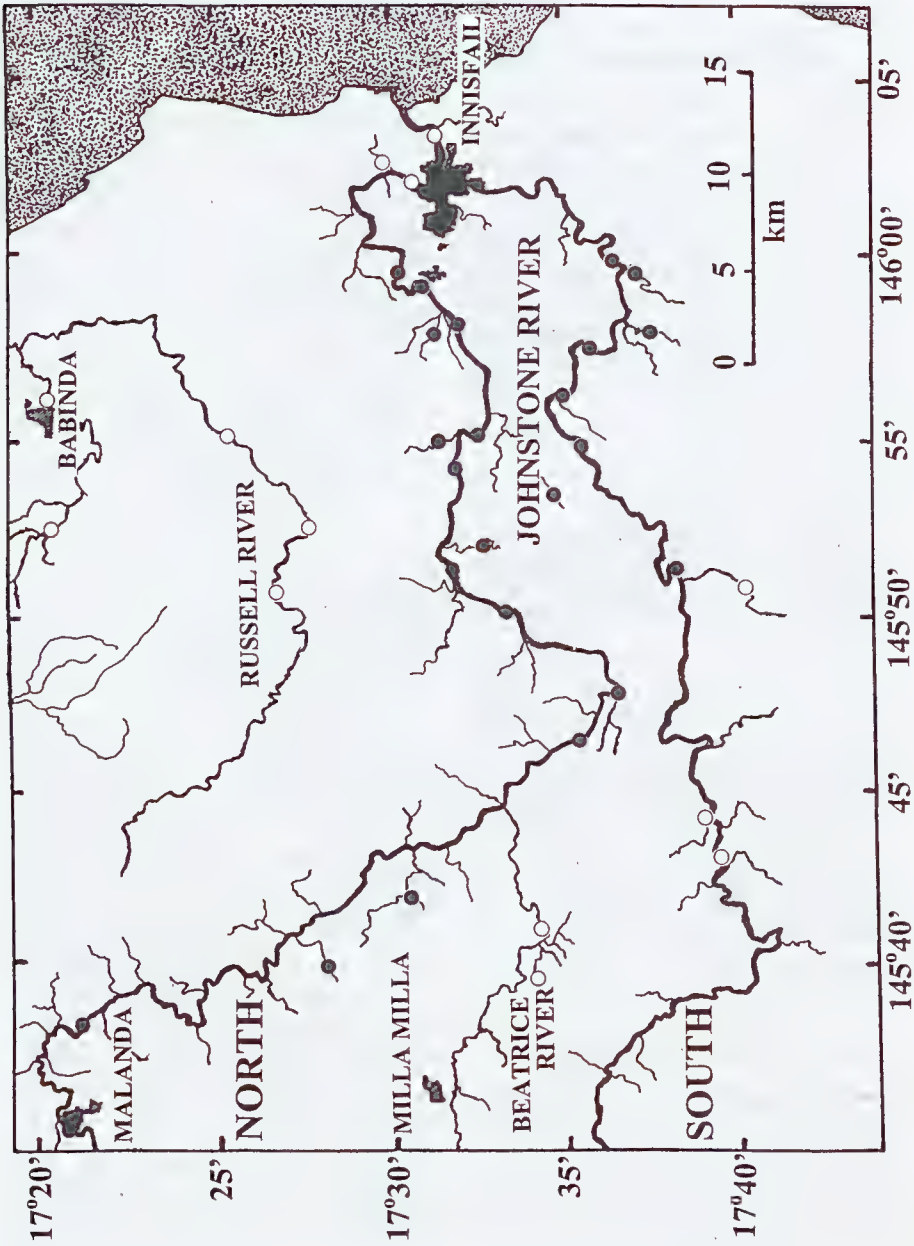
Presently all that is known of the biology of the Johnstone River *Elseya* is brief notes on their occurrence and habits (Cann, 1998) and details of their nesting behaviour (Turner, 2004). In this work I aim to provide a broader picture of the species' biology through descriptions of various aspects of their natural history (except reproduction, which will be dealt with separately; Turner, in prep.). The observations are not the result of a systematic study but were gathered rather haphazardly over a five-year period.

METHODS AND SITE DESCRIPTION

Observations occurred in all months of the year from June 2000 to December 2005. Twelve large tributaries and twenty sites along the main flow of the Johnstone River were searched. Three sites along the lower reaches of the North Johnstone River (Upper

Daradgee 17°32'S 145°55'E, Warraker Creek 17°39'S 145°55'E, Shaw's Anabranche 17°32'S 146°01'E) were regularly monitored. By day turtles were searched for by snorkeling and scanning banks and potential basking sites with binoculars. Snorkeling was mainly confined to shallow pools (<3 m deep) and rapids, due to the presence of Estuarine Crocodiles (*Crocodylus porosus*) in the deeper pools and flows of the lower reaches. Sites were searched at night by wading through shallows with a 55W (12V) spotlight. Where possible, observations were also made of turtles from elevated positions looking into the water below. Location data (latitude and longitude) were estimated using 1:50,000 scale topographic maps of the region (Cooper Point, Innisfail, MacAlister Range, Malanda, Millaa Millaa and Mena Creek: Series R733). The term 'lower reaches' of the Johnstone River refers to the river and its tributaries east of approximately 145°53'E. Captured turtles were carefully examined and a subset (approx. 150) was measured and weighed. Curved carapace length was determined with a flexible tape measure (± 1 mm). Pesola spring balances of 30 g (± 0.25 g) to 5 kg (± 50 g) capacities were used to measure mass. All females whose size exceeded that of the smallest female with palpable eggs were defined as sexually mature (= adult), while males were considered to be sexually mature (= adult) if they exceeded the size of the smallest identifiable male. Hatchlings were identified by either the possession of a caruncle or broad flattened neck tubercles and the absence of growth annuli. Juveniles were identified by the absence of a caruncle, the presence of erect pointed neck tubercles and growth annuli, and CL <150 mm. The sex of adult turtles was determined by the presence of a long thick tail in males and a short tapering one in females. Juvenile

Figure 1. Map showing the Johnstone River with portions of major tributaries indicated and sites where *Elseya* sp. has been located (solid circle) and sites where they were not located (open circle).



turtles could not be reliably sexed. Individual identifying marks were noted on all turtles. Climate data was provided by the Cairns Bureau of Meteorology. Descriptions of colouration were based on live turtles examined under diffuse natural light.

The Johnstone River drainage

The Johnstone River lies in Australia's wettest tropical region. The climate is characterised by regular heavy rainfall from about December through to April (the 'wet' season) followed by a progressive decrease in rainfall through to October/November. The wet season in the Johnstone River drainage produces annual flooding, the extent of which varies considerably from year to year. The annual rainfall within the drainage is high but varies considerably from 1675 mm (Malanda 17°21'S 145°35'E, Atherton Tablelands) to 3558 mm (Innisfail 17°32'S 146°02'E, coast) with some locations in between receiving in excess of 4000 mm. The mean minimum and maximum daily temperature varies between 19.2°C and 27.9°C at Innisfail with milder temperatures at Atherton between 14.5°C and 26.0°C. The catchment area is 163,050 ha, 54% of which is rainforest, 38% agricultural, rural residential and urban (esp. the

coastal plain) and 8% mangroves (Kofron & Smith, 2001 and references cited therein).

The two primary branches, the North and South Johnstone Rivers trend easterly from the Atherton Tablelands and traverse an altitudinal range of approximately 700 m onto the coastal plain (Figure 1). They descend through extensive rainforest-fringed gorges, significant parts of which are World Heritage listed (Wooroonoran NP) and state forest, before emerging onto the coastal plain which comprises mainly agricultural land, particularly sugar cane fields and banana plantations.

OBSERVATIONS

Habitat

The Johnstone River is characterised by relatively clear (visibility <3 m) swiftly flowing waters that comprise a series of riffles, rapids, flows, deep pools with emergent boulders and broad sluggish flows nearer the confluence (Figure 2). The banks consist of numerous stones, rock platforms and small sandy beaches. Wet-season anabranches and small islands commonly occur in the lower reaches. The substrate of the river and many of its

Figure 2. The North Johnstone River, habitat of *Elseya* sp.



major tributaries consists of dark (basalt) stones and rock platforms with sand accumulations mainly in the lower reaches. The pools frequently contain submerged rocky overhangs, logs and undercut banks. The pools and rapids are largely devoid of aquatic vegetation and apart from algae that grows on submerged rocks. The few aquatic plant species that do occur are mostly confined to clear shallow waters (e.g., *Aponogeton vanbruggenii*, *Blyxa* sp., *Hydrilla verticillata*, *Myriophyllum* sp.; see Sainty & Jacobs, 2003). Water temperatures vary from 18–30°C at approximately 1 m depth in the lower reaches (pers. obs.). The main flows of both branches are highly turbid for weeks at a time during the wet season.

Distribution

Elseya sp. is present in both the north and south branches of the river and all of the larger tributaries examined (Figure 1). In the North Johnstone River they were located from Malanda to within 5 km of Innisfail. In the South Johnstone River their western limit is probably the gorge downstream of the South Johnstone Forestry Camp (17°39'S 145°44'E) since they were not located above the gorge despite apparently suitable habitat. The eastern limits of *Elseya* in both branches were sections of river that experienced freshwater back-up due to tidal influence and they were not seen in brackish water or estuarine habitat beyond this. Only in the lower reaches of the river were *Elseya* sp. encountered a considerable distance up tributaries (e.g. Warraker Creek).

Size

Adult females are significantly larger than males with no overlap recorded in the ranges of both CL and mass. Females ($n = 47$) had mean CL = 267 ± 27.2 mm and mean mass of 1.77 ± 0.547 kg while males ($n = 22$) had mean CL = 188 ± 8.6 mm and mean mass of 0.66 ± 0.077 kg. The smallest mature female had CL = 205 mm and weighed 0.90 kg while smallest mature male had CL = 172 mm and weighed 0.48 kg. The largest female

had CL = 347 mm and weighed 3.40 kg. A female from Lake Eacham had a CL ca. 383 mm (C. Wilson, pers. comm.). The largest male had CL = 199 mm and weighed 0.75 kg. The smallest turtle captured (a hatchling) had CL = 42.5 mm and weighed 9.5 g.

Appearance

Matures

Adult *Elseya* sp. are sexually dimorphic (Figure 3a, b). Females have a broad and deep carapace with a straight front edge (to the second marginal (M2); Cann, 1998; pers. obs.); males have a more oval-shaped carapace. In both sexes the carapace is black and has maximum width at M8. The posterior marginals (M8–12) are even-edged and start to turn-up at M4 through to M7 and beyond this flare laterally. The carapacial scutes are extensively pitted. In both sexes the upper half of the neck is dark grey, the lower half is cream or off-white, the head shield and nose are dark brown or grey. The exception to this is in large (and presumably aged) females where the head coloration is piebald. In particular the head shield is a mixture of yellow and brown, the face predominantly white or cream with pale pink areas, the nose (or portions of it) bright pink and the underside of the neck white or cream with irregular but sharply demarcated areas of pale grey. The yellow head colouration of large females does not develop to the same extent as seen in *E. irwini* (based on Cann's 1997 description). Macrocephaly does not occur. The tongue and mouth are pale pink while the jaw sheaths are yellow. The plastron and plastral bridges are pale yellow or bone and heavily stained with black in some individuals. Two barbels are present, though of variable length and colour (pink, pale grey or yellow). Iris colour is dull olive brown with sparse fine silvery-gold speckling concentrated mainly around the inner rim but absent from larger individuals. The limbs and tail are uniform dark grey, the skin of the axillary pocket fades from dark to pale grey and the inguinal skin is off-white. At a given size, males have a longer tail than females. Furthermore, the distance from the edge of the

Figure 3. A mature female (left) and male (right) *Elseya* sp. from the North Johnstone River: (a) dorsal view and (b) ventral view.



anal shield to the cloacal aperture is much greater in males than in females, with the aperture in males being located beyond (as opposed to inside) the carapacial edge when the tail is straightened. In females the tail is short and tapering as it is in juveniles. The penis is dark silvery-grey to black in colour, smooth and evenly tapers to a slightly rounded tip and when fully everted is approximately the same length as the distance from the cloacal aperture to the tail tip.

Immatures

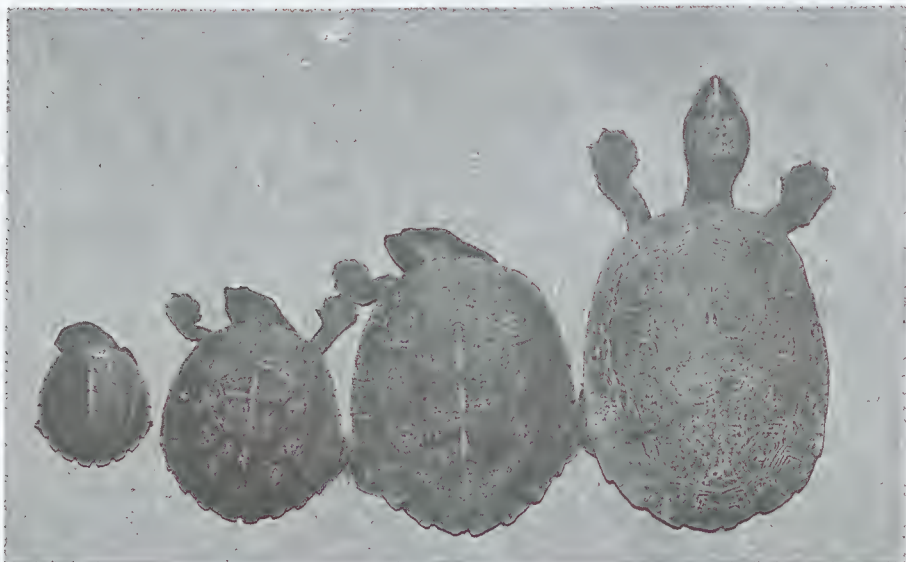
Hatchlings have an olive-green to pale brown carapace with black mottling. The vertebrals, M1-3 and costal shields have a finely textured surface, each costal having a ridge trending longitudinally. Carapace length is slightly greater than carapace width; carapace width is maximum at M7. The carapace has a strong median keel. The marginals are serrated from M3 onwards and dentate from M5

onwards and lack spiny protrusions. The plastron is off-white to pale yellow and often pale orange-pink anteriorly and also along edge of the marginals. The limbs, neck and tail are dark grey above. The lower half of the neck and throat is pale yellow, cream or off-white. The neck tubercles of hatchlings are flattened skin flaps rather than being erect and pointed as in juveniles and adults. The skin of the inguinal region is translucent. There are small, sometimes quite conspicuous regions of pale orange or pink confined to the underside of the feet, webbing between the toes and the tail. Remnants of this colouration are sometimes visible in adults. All hatchlings (and juveniles) have conspicuous silvery-gold speckling that forms a thin annulus around the inner rim of the iris and beyond this more diffuse speckling. At CL ca. 130 mm the median keel is barely apparent and the posterior marginals have started to flare laterally and are dentate from M10 onwards (Figure 4). By this size the carapace is black and there is a conspicuous pale unossified circular region in the center of the plastron; elsewhere the plastron is tinged with pale blue.

Scutes and annuli

The shedding of whole scutes was not observed in adult *Elseya* sp. and this is consistent with observations of other members of the *Elseya dentata* complex (Legler & Georges, 1993). Juvenile turtles shed whole scutes periodically. The textured surface of the hatchling scutes was gradually worn away and usually absent in individuals with CL > 130 mm. The skin on the limbs, head and neck was shed periodically in small pieces in both mature and immature turtles. Growth annuli were visible on both the carapace and plastron and were evident at all stages of maturity (Figure 5) although were often obscure in adults whose shell was smoothed by wear. Juveniles had fewer than eight annuli, with numerous fine sub-annuli also visible. Some large females had more than 30 annuli. It is unclear whether annuli can be used to accurately age *Elseya* sp. but there was a positive correlation between size (CL) and the number of annuli (Spearman $r_s = 0.93$, $P < 0.0001$, $n = 68$).

Figure 4. Morphological change in immature *Elseya* sp.: CL from left to right: 41 mm (a hatchling), 69 mm, 93 mm and 110 mm.



Growth

Hatchlings ($n = 7$) inhabiting a small pool of an anabranch initially had CL's ranging from 43 to 46 mm and after 13 months were between 58 and 68 mm, while a further year later were between 76 and 91 mm ($n = 4$). In the river, three adult females with CL's 252, 275 and 310 mm grew 7 mm (in 11 months), 4 mm (in 13 months) and 2 mm (in 12 months) respectively while a male with CL = 183 mm grew 3 mm (in 16 months). Though limited, these data suggest that asymptotic size is attained quite slowly.

Ectosymbionts

Three kinds of ectosymbionts occurred on turtles: algae (at least two types), flatworms and oligochaetes. Algae were present on all turtles except hatchlings and comprised both filamentous and non-filamentous types which grew on all parts of the shell, head shield and skin. In adults a dark green algal 'skin' often grew on the face, tympanum and the femoral and anal shields of the plastron. In juveniles, the bridge and plastron (esp. the underside of marginals) were often colonized by black algae that was confined to that the part of the scute away from the growth annuli. More than 70% ($n=112$) of turtles examined harboured

flatworms, particularly in the inguinal pocket, along with brownish clusters of the flatworm egg cases (Figure 6). The flatworms were identified as the triclad platyhelminth *Bdellasimillis barwicki*, a species that has been recorded from several Australian chelids (Ball, 1976; Richardson, 1970). The largest flatworm loads (in terms of the relative area of skin covered) occurred in juveniles. The flatworms (up to approx. 12 mm long) often formed clusters on the skin and were firmly attached. No blood or visible wound was evident upon their removal. Recaptures of individual turtles ($n = 15$) indicated that flatworm loads were acquired and shed at various times throughout the year. Similarly the extent of filamentous algal growth on the head shield and carapace varied throughout the year as seasonal conditions changed and as skin and scutes were shed. Oligochaetes occupied the axillary and inguinal pockets, neck and along the edges of the anal scutes of both adult and juvenile turtles. Their encasings resembled folds of dead skin. They were less commonly encountered than flatworms. The extent of symbiont loads in individual turtles, and the differences in loads between juveniles and adults, probably reflects the different microhabitats they occupy (see below).

Figure 5. Growth annuli on the carapacial scutes of an adult *Elseya* sp. (more than 20 are visible).

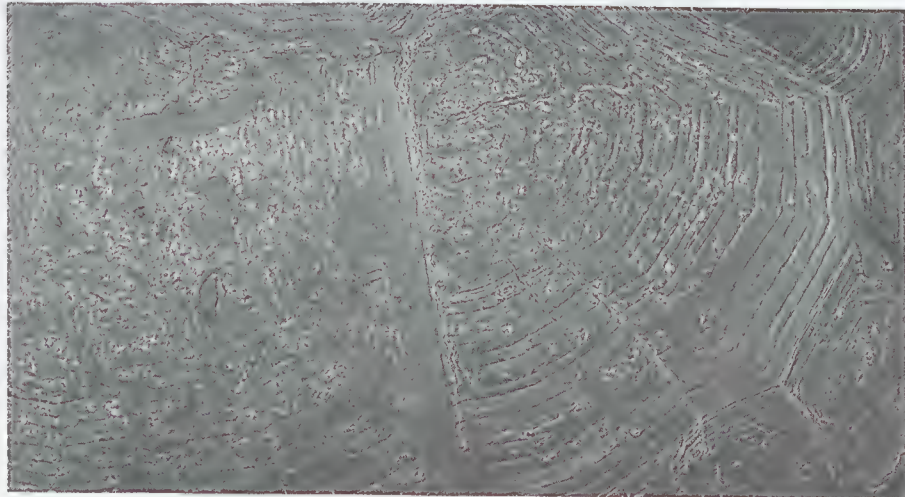
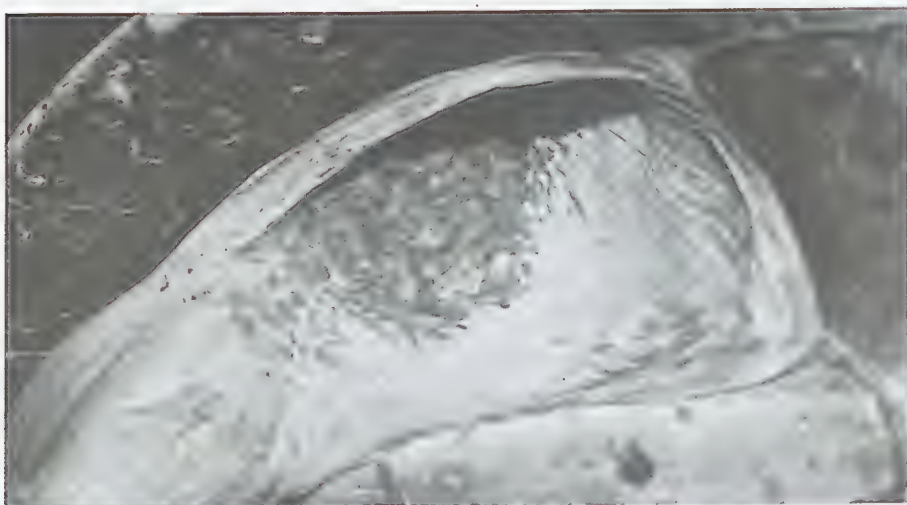


Figure 6. A cluster of the flatworm *Bdellasimillis barwicki* (along with egg capsules) inside the inguinal pocket of an immature *Elseya* sp.



Sympatry

In parts of the Johnstone River drainage *Elseya* sp. occurred in microsympatry with the Saw-shelled Turtle *Elseya latisternum*. This sympatry occurred in both branches of the river and in some tributaries. *Elseya* sp. were always more numerous than *E. latisternum* in these situations. By contrast, *E. latisternum* were present in nearly all small permanent watercourses in the drainage and occupied upland and lowland streams where *Elseya* sp. did not occur. In tributaries that descended into the gorge of the North Johnstone River (e.g., Douglas Creek 17°36'S 145°47'E, Henrietta Creek 17°36'S 145°45'E), *E. latisternum* were located in plunge pools and elevated sections of these creeks, but *Elseya* sp. were located only close to the junction of the river. Near the headwaters of the North Johnstone at Malanda, *E. latisternum* were abundant but *Elseya* sp. were uncommon. A similar pattern was observed in the upper reaches of the South Johnstone River. Whether these distribution patterns of the two species reflect preferences for different habitats or are the result of competitive exclusion is not known.

Use of habitat

All turtles were located within 250 m of riffle zones (either up or downstream). Adults by day resided mainly in deeper pools and flows or on basking sites at pools. At night, adults would regularly move into the shallows of large pools and flows, as well as adjacent smaller pools. Juveniles and hatchlings were seen in deep pools but were regularly found in large numbers in shallow stony bottomed pools (<1 m deep) and rapids. When encountered in rapids by day, both juveniles and adults were nearly always standing still and facing into the current or were wedged in between stones. When water current was strongest (i.e., during the wet season) turtles were found along the edges of flows where the current was weaker. Hatchlings were often located in rapids, riffles and shallow pools with relatively strong currents in depths as little as 70 mm. In permanent anabranches of the North Johnstone River such habitats were often situated near junctions and juveniles were common there. For example, in one anabranch more than 80 different juveniles (CL < 100 mm) were located in a 100 m section over a six month period near the junction with the main flow.

Activity

Elseya sp. was active in water in all months of the year. Adults were active both during the day and night, while juveniles were diurnal. No juveniles were observed active at night and the few that were located at night ($n = 8$) were secreted amongst stones on the substrate with the head and limbs retracted into the shell and the lower eyelid covering the eye, as if asleep. The same activity patterns were observed in captive juveniles. All adults encountered at night were active and were either standing still with limbs out in contact with the substrate and the head extended (often downwards as if investigating something of interest), or walking ('prowling') slowly along the substrate. Adults and juveniles were seldom seen to surface breathe.

Basking

Basking occurred in all months of the year. On sunny days *Elseya* sp. would sometimes emerge to bask on logs or rocks situated mid-stream or on roots, logs or rocks that protruded from banks into the water. All stages of maturity engaged in aerial basking, however the species was never seen to regularly bask, despite many apparently suitable opportunities to do so. Basking was the only time that adult males and immatures were seen out of the water (mature females emerged annually to nest). Basking aggregations occurred on small platforms and then no more than eight turtles of different sizes were present and in close proximity to each other. When basking, individuals of disparate or similar sizes would sometimes be in direct contact with each other and the emergence of other individuals was not observed to elicit any response. Adults that had been basking for at least 20 minutes would repeatedly wipe their face against their front limbs. Some hatchlings and juveniles ($n = 6$) were observed at rest (limbs and head tucked-in) completely exposed to the sun in warm shallow water, suggesting that they might engage in some form of aquatic basking. Some turtles were located in pools where opportunities to bask were limited by shade (closed canopy) or lack of basking sites (verti-

cal banks and few or no emergent logs or rocks).

Aggregations

Irrespective of size, individual *Elseya* sp. were typically located singly in the water. At night when adults entered the shallows, individuals of the same or different sexes were often seen in close proximity (<1 m apart). Occasionally pairs of hatchlings and juveniles ($n = 11$) were located only centimeters apart during the day. In no instances were interactions evident between them. One curious observation occurred during the day in late October and consisted of eight adult females (seven with CL > 300 mm) occupying a small (15 m x 4 m), clear, shallow (max. depth 1.5 m) pool of an anabranch. As there was no significant cover, they were easily observed swimming and walking along the sandy substrate in close proximity to each other for about half an hour; once alerted to my presence (on the bank) they retreated to the substrate where movement ceased.

Hatchling behaviour

Hatchling *Elseya* sp. that were kept in groups in plastic containers without a substrate occasionally clasped each others' shells with their claws to form an irregular-shaped cluster of between three and ten individuals. When clustered, individuals were at various orientations (but never completely up-side-down) and were nearly motionless. Hatchlings sought refuge beneath artificial surface cover (floating plastic container lids) sometimes during the day and routinely at night. No aggressive interactions were observed between similar-sized hatchlings or juveniles from either the same or different clutches when housed together. However aggressive interactions, such as biting and chasing, were seen amongst captive juveniles of disparate sizes (different cohorts).

Cloacal breathing

Cloacal respiration occurs in *Elseya* sp. and cloacal gaping was observed in individuals both in and out of the water (Cann, 1998; pers. obs.). A wet finger placed near the

cloacal opening indicated air being forced regularly in and out of the cloaca. Debris on the substrate beneath the cloacal opening of hatchlings could clearly be seen to regularly move back and forth at rate of about once a second.

Responses to disturbance and handling

Basking turtles invariably retreated into the water when approached within 15-30 m and typically sought refuge only a short distance from the basking site on the substrate, wedged between or beside stones. Turtles were observed to vacate small pools of anabranches by crossing natural fords into deeper adjacent pools in response to me entering the water. When approached on the substrate, mature and immature turtles alike would typically cease moving, except for slight movements of the head in order to watch the perceived danger. When approached at close quarters (<1 m), some turtles would scramble away, usually swimming in a rising arc for several metres before dropping to the substrate and then if still pursued, would reverse their course and swim low to the bottom (see Legler & Cann, 1980). Females in particular were very fast, agile swimmers that were capable of swimming against strong currents and up rapids (Cann, 1998; pers. obs.). Other individuals would not move until they were touched.

When handled, *Elseya* sp.'s primary inclination was to escape rather than bite and when placed on the ground the head was withdrawn and a rapid scurry ensued away from the handler. Males would typically evert the penis during handling. Adults were generally not inclined to bite unless movements or objects were placed near the head. Prodding of the nose would usually elicit mouth gaping. By contrast juveniles would nearly always attempt to bite when captured and would mouth gape and fully distend the throat. Hatchlings maintained in captivity and regularly handled were generally non-aggressive and usually would fold the head under the shell when handled. Adults and juveniles were able to right themselves when placed on

their backs by arching the neck back until the snout had a purchase on the substrate, then using it as a lever to flip the shell upright, with the help of the limbs.

Crypsis

The close resemblance between the dark carapace of *Elseya* sp. and the stony substrate they inhabit, combined with their tendency of remaining still when approached, made both adults and juveniles difficult to see even in clear shallow water. It was often their sudden movement when approached too closely that revealed their presence. Juveniles were well camouflaged on stony substrates due to their nearly circular shape and a coating of silt and/or algae on the carapace and head. Females with their pale heads were more conspicuous at night in the spotlight because of these features.

Movements

On two occasions in December, prior to the onset of the wet season, 'groups' of turtles were observed moving up a tributary from the river at night. These two groups comprised approximately a dozen adults (both sexes) that were all walking along the substrate and heading upstream. In October/November when water levels are at their lowest, adult *Elseya* sp. have been observed emerging partially from the water at night to access shallow side-pools adjoining the main flow. Turtles were observed feeding in these pools at night and by day had disappeared, presumably back into the main flow. In another instance, heavy rain following a dry spell in November seemed to trigger the nocturnal movement of more 20 adult turtles from the river into two shallow pools of a tributary where they were observed feeding. There was no indication that *Elseya* sp. travelled over dry land in search of pools. The movement of both mature and immature turtles between adjacent pools of tributaries was evident both within and between years. The greatest distance an individual moved was approx. 350 m along a flow of the river. By contrast some adults ($n = 13$) and juveniles ($n = 15$) spent most, if not all of their time, in just one pool.

Diet

Information on the diet of *Elseya* sp. was obtained from faecal and regurgitated samples ($n = 22$), by direct observation of turtles feeding and through observations of captive individuals. All samples consisted primarily of plant material, comprising algae, leaf, stem and root fragments and also figs (*Ficus* sp.). In two samples were fragments of Black Bean nuts (*Castanospermum australe*). These were in fruit at the time samples were taken and produce large seeds (30–50 mm; see Cooper & Cooper, 1994: 68). One turtle was also observed feeding from a distance and on investigation Black Bean nuts with obvious bite marks were located on the substrate. In one faecal sample was a seed of Mueller's Damson (*Terminalia muelleri*) that were fruiting abundantly at the time (January). *Elseya* sp. was also observed attempting to feed on the large orange fruits of the Brown Walnut (*Endiandra montana*; see Cooper & Cooper, 1994: 116) and the small red fruits of the River Cherry (*Syzygium tierneyanum*) that had fallen into the water. Leaves, both fresh and dried (brown), were consumed in small bite-sized pieces especially late in the year when leaf litter was most abundant. Feeding 'aggregations' of up to 12 adults (both sexes) were observed consuming filamentous algae at night that had 'bloomed' in the shallow water (<45 cm deep) of a 20 m² cul-de-sac that had formed in an anabranch. Because algae trap silt and sediment, small amounts of this were often present in faecal samples ($n=12$). In the wild, *Elseya* sp. were occasionally observed scraping algae with the upper jaws from submerged stones and rock platforms, leaving characteristic scrape marks on these surfaces. Some stone surfaces had the appearance of having been extensively 'grazed'. Adults were observed cropping non-native pasture grasses at night when freshwater back-up from tidal flow submerged these grasses lining the river. Turtles were observed consuming blade and stem portions of the grasses. Juvenile *Elseya* sp. (CL <100 mm; $n = 3$) introduced into an aquarium with

numerous aquatic ribbon grasses and broad-leaf plants within a matter of weeks had severely cropped all plants to extent that the turtles had to be removed!

Most of these vegetative food sources were not available year round but were seasonal, especially the fruits (Cooper & Cooper, 1994; pers. obs.) and the filamentous algae, which were scoured from rocks during wet season flooding. Algae were most abundant when water levels were low and rain infrequent (September through to December). Whether the sparsely occurring native aquatic plants *Blyxa* sp. and *Aponogeton vanbruggenii* are consumed in the wild by *Elseya* sp. is not known, although they were readily consumed by captive juveniles.

The extent to which *Elseya* sp. consume animal food is unclear. Remains of freshwater prawns (*Macrobrachium* sp.) were evident in two faecal samples and prawns reside in amongst stony fissures where *Elseya* sp. forage. Turtles in the wild tolerated the presence of fish in quite close proximity to them and no attempted predation was observed. In captivity however, juveniles pursued and attacked small fish. Anglers in the region have often caught *Elseya* sp. (juveniles and adults) on a variety of live and dead fish baits, worms and even bread (B. Dryden and P. Webb, pers. comm.). Captive juveniles readily consumed commercial fish and turtle pellets (comprising primarily fish/shrimp meal), raw lean meats (including beef and fish) as well as small live mosquitofish (*Gambusia* sp.). A captive adult fed on kangaroo and pig meat, a variety of (dead) fish, fish pellets, tinned dog and cat food, as well as a variety of fruit and vegetables (D. Green, pers. comm.). A small population of *Elseya* sp. in Mena Creek (17°39'S 145°58'E) has been fed for years on fish pellets (pers. obs.). Large bivalve molluscs that occur in the lower reaches of the river several kilometers beyond the tidal influence overlap with *Elseya* sp. and may constitute another food source.

In the wild, *Elseya* sp. approached food items cautiously and appeared to 'smell' them

before eating. By contrast, long-term captive turtles were less cautious in their approach and proved to be quite uninhibited, aggressive feeders even when maintained in mixed species groups (D. Green, pers. comm.; pers. obs.). When feeding on large items such as fruits, the front feet were used to stabilise the item. Often they would tear and rip at large items by jerking the head.

Predators and mortality

Predation of turtles was not observed directly in the wild. Estuarine Crocodiles (*C. porosus*) possibly pose a threat to adult *Elseya* sp. in the lower reaches of the river where they share the same habitat, although they occur in relatively low densities (0.15 individuals/km) in the Johnstone River and were considered depleted compared to other rivers on Cape York Peninsula (Täplin, 1987; Kofron & Smith, 2001). Estuarine Crocodiles rarely extended far up tributaries except in the lower reaches that were within tidal influence (e.g., Ninds Creek, Victory Creek and Bamboo Creek - all close to Innisfail). Remains of *Elseya* sp. (shell fragments) were located at a regularly used basking site of a crocodile (V. McIvoy, pers. comm.). Further indirect evidence of crocodiles as predators comes from the occurrence of three adult turtles with serrated-edged bite marks on the posterior marginals that are difficult to attribute to any other potential predator.

The occurrence of four dead adult females on land at nesting areas indicated that nesting *Elseya* sp. were subjected to terrestrial predators. In two instances wounds had been inflicted to the head and neck but the shell and limbs were intact and undamaged (other turtles were badly decomposed). Water rats (*Hydromys chrysogaster*) were significant predators of *Elseya* sp. nests (Turner, in prep.) and might conceivably attack nesting females, although observations of Water Rats killing adult *Emydura krefftii* indicated that they eat most of the soft parts (Cann, 1998: 31).

Small Bull Sharks (*Carcharhinus leucas*) have been seen and caught in deep pools up to 25

km from the Johnstone River confluence in sections where *Elseya* sp. are relatively common. Sharks would probably include turtles in their diet (Cann, 1978: 22).

Juveniles are potentially vulnerable to a larger range of predators compared to adults. Longfinned Eels (*Anguilla reinhardtii*) were very common in rapids and shallow pools where they were often seen foraging at night. Some eels develop quite large heads and have a mouth gape physically capable swallowing hatchling and juvenile *Elseya* sp. (pers. obs.) but no instances of predation were observed, although records of eels preying on other juvenile turtles exist (Cann, 1978: 21-22; 1998: 30). Spotted Barramundi (*Scleropages leichardtii*) were commonly seen in deeper pools and flows of the river but were absent from shallow pools where juvenile *Elseya* sp. were most abundant; they are known to prey on hatchling turtles (Phillott & Parmenter, 2000). Jabiru (*Ephipporhynchus asiaticus*), Egrets and Herons (*Ardea* sp.) feed in riffles and shallows where juvenile *Elseya* sp. occur and Jabirus include turtles in their diet (Worrell, 1966: 85).

Injury and disease

Injuries to adult turtles were evident in the form of indented marginals, white scars on the neck, tail and limbs and fractures of the shell. Scars resembled thin white ocelli or arcs and were consistent in shape and size with bites from conspecific males (see right rear limb of female in Figure 3b). These scars were regularly observed and occurred in both sexes. Shell fractures were not commonly observed and were likely to be the result of falls and collisions with rocks ($n = 7$). Limb injuries were rare with one juvenile turtle missing its entire right rear limb, but it was in good condition otherwise. Three adult turtles had each lost one eye, possibly through injury.

Most *Elseya* sp. were in good health with no obvious signs of disease. However, eight adult turtles were encountered whose eyes were entirely milky. The condition had impaired the

vision of affected individuals (four were completely blind) and this was confirmed by the lack of response of these individuals to visual stimuli.

Finally, landholders in the Innisfail district have noted the occurrence of dead adult turtles in water and also washed-up on beaches and banks following diesel spills (which are rare).

DISCUSSION

The habits of the Johnstone River *Eseya* are similar in many respects to other bottom-dwelling species inhabiting coastal Queensland rivers. In particular, diet, habitat use, cloacal breathing and some aspects of behaviour are shared by these species. The diet of the Johnstone River *Eseya* closely parallels that of the Burnett River *Eseya* (Armstrong & Booth, 2005) and other members of the *E. dentata* complex, which have been recorded feeding primarily upon the fruit (esp. figs) and leaves of riparian vegetation, filamentous algae and carrion when available (Legler, 1976; Cann, 1978: 19, 64; Kennett & Russell-Smith, 1993; Kennett & Tör, 1996; Allanson & Georges, 1999; White, 1999). It is possible that annual wet season flooding presents different feeding opportunities to Johnstone River *Eseya* since turtles gain access to vegetation well away from that lining watercourses. The absence of water impoundments such as dams or weirs along both branches of the Johnstone River and the presence of numerous riffles would ensure relatively high levels of dissolved oxygen in the water. This, combined with the ability to take in oxygen through cloacal breathing, probably accounts for the observed lack of surface breathing. The peculiar 'clustering' behaviour observed in captive hatchlings has been observed in juvenile Fitzroy River Turtles *Rheodytes leukops* under similar conditions (Legler & Cann, 1980) and might reflect an instinctive behaviour for these bottom-dwelling turtles to be in contact with a surface that can be gripped. The aggressive reaction of juveniles when handled (com-

pared with adults) has been similarly noted in *E. irwini* (Cann, 1997) though the reasons for it are unclear.

The Johnstone River *Eseya* appears to be a slow growing, potentially long-lived, mainly herbivorous, bottom-dwelling turtle dependent upon flowing water, stony substrates and windfall leaves and fruit. The drainage supports large populations of these turtles and the frequency with which individuals from a broad range of size classes were encountered suggests that recruitment is occurring (pers. obs.). While sections of the river system and its tributaries lie within national park and state forest boundaries and are therefore protected, parts of the watershed and the lower reaches remain vulnerable because of human activity, particularly agricultural practices in these areas. It seems there are no immediate threats to the species' survival but there are three potential threats in the medium to long term: (i) the presence of introduced species, especially the Niger Cichlid (*Tilapia mariae*), (ii) changes in riparian vegetation and (iii) changes in water flow and water quality.

Regular users of the river have observed a substantial reduction in aquatic vegetation that they attribute to the presence of the invasive Niger Cichlid. The species is known to feed mainly on plants (Allen *et al.* 2002: 370) and was observed feeding on aquatic grasses in the Johnstone River (pers. obs.). Cichlids may therefore compete directly with *Eseya* sp. for food. The invasive deep-water grass *Hymenachne* (*Hymenachne amplexicaulis*; DNRM, 2001) has also invaded some sections of the river at the expense of native aquatic vegetation. While at present both species occur mainly in the lower reaches of the drainage, there is clearly a need to ascertain what impact they are having on the river's ecosystem.

Eseya's exploitation of leaf and fruit fall from trees lining the river (and its tributaries) has implications for their survival, particularly in the lower reaches where vegetation clearance has in the past been extensive, often up to the

edge of banks (pers. obs.). *Elseya* sp. exist in these sections nonetheless and a comparison of the diets (and ecology) of these and upstream populations would be useful in identifying how changes in vegetation affect the species.

Relative to other rivers in the Wet Tropics region, the Johnstone River has high levels of pollutants, especially fertilizers and high sedimentation rates due to hill slope and stream bank erosion (Armour *et al.*, 2004: 15-16, 36). The long-term effect of exposure to pollutants on the aquatic ecosystem is not presently known. It is possible that high sedimentation rates may affect the efficiency of cloacal respiration in turtles. The occurrence of *Elseya* sp. with impaired vision is of concern since Cann (1993, 1998: 212) has observed apparently the same condition in *Elseya bellii* and *E. latisternum* from NSW rivers and attributed its occurrence to the chemical pollution of waterways in agricultural areas. The incidence of the condition in the Johnstone River *Elseya*, along with pollution levels, should be monitored.

Outside of the Johnstone River drainage, members of the *E. dentata* complex are known from Hartley's Creek (16°39'S 145°34'E; Goode, 1967: 54) almost 200 km to the north of Innisfail. Cann (1998) does not regard these turtles as necessarily different from those of the Johnstone River but he does note some differences in morphology and colouration. However it is uncertain whether the Hartley's Creek *Elseya* is endemic for several reasons: (i) the site where specimens were located is the former site of Hartley's Creek Zoo/Crocodile Park (established in the 1930s; D. Green, pers. comm.) and the possibility of the release/escape of captive turtles from elsewhere cannot be excluded, (ii) only small numbers (<10) have been located and (iii) no *E. dentata*-like turtles were located in the Russell, Mulgrave or lower Barron River systems situated in between the Johnstone River and Hartley's Creek (pers. obs.). Furthermore releases of Johnstone River *Elseya* have occurred elsewhere in the region with specimens located in an isolated crater lake

(Lake Eacham 17°12'S 145°38'E; C. Wilson, pers. comm.) and Tinaroo Dam on the Atherton Tablelands and are possibly present in the upper reaches of the Barron River (Jennings, 1985; pers. obs.). While not conclusive, this information suggests that the occurrence of the Hartley's Creek *Elseya* may be the result of human activities. A detailed morphological and/or biochemical comparison of specimens with the Johnstone R. *Elseya* should resolve the matter conclusively.

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OBSERVATIONS OF THE SHORT-TERM MOVEMENT, MICROHABITAT AND TEMPERATURE OF A FREE-RANGING KEELBACK, *TROPIDONOPHIS MAIRII* (SERPENTES: COLUBRIDAE) IN A TROPICAL RAINFOREST STREAM

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INTRODUCTION

The Keelback (*Tropidonophis mairii*) is a medium-sized (to 0.8 m snout-vent length, 250 g; Brown & Shine, 2005), non-venomous, natricine colubrid (Wilson, 2005). Both nocturnal and diurnal, the species typically occurs near water-bodies throughout northern Australia (Wilson, 2005) where it preys primarily on frogs, but also consumes lizards and fish (Shine, 1991).

The use of miniature radio-transmitters to track small animals such as snakes has allowed the collection of information on the movement and microhabitat use of a wide range of animals previously too small to track (Weatherhead & Hoysak, 1989, Webb & Shine, 1997, Fitzgerald *et al.*, 2002, Whitaker & Shine, 2003). However, despite recent research investigating the ecology of *T. mairii* on the Adelaide River floodplain (Brown, 2002, Brown & Shine, 2002, 2004a-b, 2005), there is nothing known about the movement and habitat use of *T. mairii* in other habitat types.

The following observations on the movement, microhabitat and temperature of a free-ranging *T. mairii* occurred during a radio-telemetry study of rainforest stream frogs in North Queensland. During the study, a *T. mairii* consumed one of our study animals, including its attached radio-transmitter, allowing us to track the diurnal and nocturnal habits of the individual for a period of four days.

METHODS

All observations of the *T. mairii* occurred adjacent to an unnamed stream in Tully Falls Forest Reserve, north Queensland (17°48'S

145°41'E; 70 m asl). The study stream had a low channel gradient with limited bedrock confinement and a forested riparian zone characterised primarily by closed rainforest.

Radio transmitters (models BD-2N and BD-2NT; Holohil Systems Ltd., Ontario, Canada; weighing approximately 0.58 g) were fixed to a harness made of silicon tubing and attached externally around the waist of the frog. The transmitters were temperature-sensitive, and by recording inter-pulse frequency, it was possible to remotely measure the temperature of the transmitter. We tracked the animals using a Habit Research HR2500 Osprey VHF Receiver and a three-element folding Yagi antenna (A.F. Antronics, White Heath, Illinois, USA). During the course of the study, one of the study animals, an adult female *Litoria jungguy* (59.8 mm snout-vent length, 27.5 g weight) was eaten by a *T. mairii*, providing us with the opportunity to track the snake, recording its movement, habitat use and temperature over several days. Temperature and relative humidity at the site was recorded using a whirling hygrometer.

OBSERVATIONS

The frog was last seen at 1310 hr on 4 September 2005, but when we attempted to locate the frog that night (2020 hr), we could not find the individual. Rather, the signal was strongest underneath the base of a dead tree, approximately 20 m from where the frog was last observed. This location was highly uncharacteristic for the frog species (J. Rowley, unpubl. data), and it was at this point we realised that it was likely that we were now tracking a snake rather than a frog.

Table 1. Movement, habitat and body temperature of the *T. mairii* tracked. Ambient temperature and relative humidity were measured using a whirling hydrometer at a height of approximately 1 m above ground level.

Date	Time	Horizontal distance from water (m)	Elevation above water (m)	Distance moved between observations (m)	Habitat description	Snake body Temperature	Ambient temperature	Relative humidity (%)
04.09.05	2020	1	1	20	Under base of dead tree	-	20.5	91
05.09.05	1330	1	1	0	Under base of dead tree	25	23.5	67
05.09.05	2130	5	5	50	In underground burrow	24	19.25	98
06.09.05	1325	5	4	1.5	Underground burrow	26	25.5	62
06.09.05	2040	2	1	18.5	Underground burrow	23.5	21.5	89
07.09.05	1215	3	2	2.5	Underground burrow	23	25.5	74

For the next three days, we continued tracking the snake, locating it once a day and once a night. The snake was always located underground, either within cavities under a dead tree, or in various burrows or hollows under the soil (Table 1). On a number of occasions, entrances were observed leading into these cavities, and on 6 September 2005, we could see the head of a snake near one of these entrances. By using the radio-receiver, we were also able to detect the snake moving through this system of underground cavities, which appeared to be at least several meters in extent.

Although the snake moved up to 50 m between successive observations, it was always located in close association with the stream (<5 m; Table 1). In addition, the retreat sites used by the snake were often saturated with water, unlike adjacent substrate.

The internal temperature readings obtained from the radio-transmitter appeared related to, but slightly higher than ambient air temperature (Table 1), and were consistently higher than those recorded previously by the same transmitter, when tracking the frog.

During the diurnal survey on 7 June 2005, we used a snake hook to probe what appeared to be a burrow entrance where the radio-signal was the strongest, and a female *T. mairii* emerged. The snake measured 680 mm in body length, 140 mm in tail length and had a gape of 17.5 mm. There was a distinct bulge mid-way down the snake, which corresponded with the strongest radio-signal. The snake was released at point of capture after measurements were taken.

Some days after release we found a fresh *T. mairii* skin shed attached to a large rock submerged in the stream, and beneath the rock we found a tracking device that had been attached to another *L. jungguy*, indicating that either the same individual, or another *T. mairii* had predated upon another of our study animals.

DISCUSSION

The short-term movements of the *T. mairii* tracked in this study are consistent with the notion that the species is restricted to areas around water-bodies (Shine, 1991).

An active forager (Brown *et al.*, 2002), the movements observed by *T. mairii* in this study may represent foraging bouts. However the snake had only recently ingested a relatively large prey item, which was still mid-body at the conclusion of the field trip. It is possible that we disturbed the snake during our tracking and it was attempting to avoid us. However we believe this is unlikely as we only visually encountered the snake once during the tracking, aside for the last tracking period when we captured the snake. At other occasions, we simply noted where the snake was located underground, and remotely recorded the temperature of the transmitter.

Perhaps not surprisingly, snake body temperature was almost always higher than ambient. This may be typical of tropical species, with the water python *Liasis fuscus* having both minimum and maximum temperatures higher than ambient (Shine & Madsen, 1996).

Although brief, these observations of a free-ranging *T. mairii* provide us with valuable data on the ecology, thermoregulation and dietary habits of an Australian colubrid snake in a rainforest environment, information that is often difficult to obtain due to the secretive nature of these animals and habitat complexity of the environment.

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PREDATION, BY THE FERAL HOUSE MOUSE (*MUS MUSCULUS*), OF MCCANN'S SKINKS (*OLIGOSOMA MACCANNI*) CONSTRAINED IN PITFALL TRAPS

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In March 2005, one of us (ML) observed three successive predation events, all inferred to be by the house mouse, *Mus musculus*, on McCann's skinks, *Oligosoma maccanni*, captured in pitfall traps set for lizards on Kaitorete Spit, Canterbury, New Zealand, at 43°50'S 172°38'E. The first instance resulted in the death of two sub-adult (snout-to-vent length (SVL) = 48 mm) male skinks, both of which were caught the previous day in the same trap. Both skinks were partially eaten and without tails. Their feet remained intact; hence skinks could be identified by their respective toe-clip combinations. On close examination of the contents of the pitfall trap (4.5 L white plastic 'Spacesaver'; Containment Solutions, Christchurch, New Zealand), mouse scat was found. The predator was able to escape through the 1-2 cm gap between the top of the pitfall trap and the plywood lid. The lid remained in place, held off the ground by wooden spacers glued under each corner and secured in place with steel pegs. Two days later, the remains of an unmarked juvenile skink were found in the same trap, also partially eaten and tail-less. At this point the trap was closed while other traps at the site remained operational for another day. On the final day, the remains of another juvenile skink were found in a trap 12 m away.

Although we do not know whether these skinks were killed by the same individual, it is not inconceivable that a mouse could learn to repeatedly visit pitfall traps to check for prey items. No other incidences of predation from pitfall traps were observed at this site despite considerable trapping effort (600 trap-days). Other predators detected within 1 km of this site using live capture (Holden) traps, sand plots and tracking tunnels were hedgehog, *Erinaceus europaeus occidentalis*, feral cat, *Felis catus*, and weasel, *Mustela nivalis*, all of

which are known to include lizards in their diet (Gillies, 2001; King *et al.*, 2001; Jones *et al.*, 2005).

Research examining the effect of rodent predation on New Zealand lizards has focused almost exclusively on rats, *Rattus* spp. The impacts of mouse predation on lizard populations remain poorly understood but should not be underestimated. On Mana Island, Wellington, New Zealand, *Oligosoma* skinks made up 20-25% of mouse diet in some autumn-to-early winter months (Pickard, 1984). Mice were also observed entering pitfall traps, leaving scat and partially eaten lizards, and in one case, eating a still-alive skink caught within (Newman, 1994). Mice also preyed on lizards caught in pitfalls at Pukerau Bay, Wellington (Towns & Elliott, 1996). Here, mortality reached a maximum of 7% of the total captures made during one field season but did not exceed 2% in most years.

Mice have also killed reptiles held in captivity, either directly (Burt, 1927) or indirectly – for instance, an adult tuatara, *Sphenodon punctatus*, was wounded and died from the subsequent infection (Newman, 1986). Over a two week period in October 1925, 26 out of 30 captive lizards, *Crotaphytus collaris collaris*, were killed by a mouse, and mortality ceased following capture of the mouse (Burt, 1927). All of the victims sustained injuries to their tails, and several had as many as three of their feet gnawed away. When approached by the mouse, lizards opened their mouths and faced it squarely. The mouse then darted around the lizards and nipped their tails from behind. Three lizards were observed to be successively attacked in this fashion. These attacks coincided with a period of cooler weather, apparently giving the endothermic mammal the advantage.

Although interactions between mice and lizards constrained in pitfall traps or held in captivity may not be representative of encounters in free-living populations, it is clear that mice do include lizards in their diet. Mouse predation may have greater impacts on lizard populations during cooler weather when lizards are less able to defend themselves (Burt, 1927; Pickard, 1984). Lizards may also be more vulnerable to predation at times when mice undergo dramatic increases in abundance. Such irruptions can occur when food suddenly becomes plentiful (e.g. beech *Nothofagus* spp. masting events) or following the removal of mice predators (Ruscoe, 2001). The removal of stock - as done at many sites nominated for restoration - can also produce mouse irruptions through habitat changes that favor mice (e.g. proliferation of rank grasses; Towns & Elliott, 1996).

Eradicating or reducing mice numbers through trapping and poisoning is likely to have direct (reduced mortality of lizards) and indirect benefits (reduced abundance of predators that rely on mice as primary prey) for at least some species of New Zealand lizards. Since house mice generally prefer areas with dense ground cover (Ruscoe, 2001), habitat manipulation provides another means whereby mice numbers could potentially be controlled (Towns & Elliott, 1996).

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LETTER TO THE EDITOR

VOUCHER SPECIMENS

One of the fundamental methods in zoology, especially field zoology, is to take for preservation in a museum one or more voucher specimens of the species being studied. This is done for two reasons. First, to verify an identification if a question should arise about the accuracy of the original identification. And second, to determine to which species the specimens belong should a new species be described out of the old species.

In the last few years there has been a tendency to not take voucher specimens. This is true for professional zoologists as well as unpaid zoologists. And it a trend that is evident in the articles in *Herpetofauna*. It is becoming increasingly rare to read an article in the zoological literature that is backed up with a voucher specimen.

There are several reasons why fewer people are taking vouchers, all related to increasing prohibitions on how humans can interact with wild animals. For example, in most parts of Australia it is now illegal to even disturb an amphibian or reptile in the wild without having both a scientific licence and approval from an animal care and ethics committee. Furthermore, to kill an animal requires not only these authorizations but also either a demonstrated expertise or formal training in methods of properly killing animals. And this says nothing about then gaining authorization to obtain the common euthanasing chemicals. I will only point out in passing that many non-scientific activities result in the annual killing by humans of hundreds if not thousands of amphibians and reptiles with not the slightest regard to any of these authorizations, as for example, burning off and land clearing.

The problem with making it increasingly difficult to take voucher specimens legally is that we are building up data bases that will be increasingly corrupted over time with misidentifications, and we will have no way of going back and cleaning them up. And yet, these are the very data bases that provide the basis for many land management and conservation decisions. Even faunal surveys undertaken now by universities and government agencies often do not take vouchers, and one has to ask if it is worthwhile to continue spending people's tax money on projects that employ such poor scientific procedures.

What is to be done? Very little I suspect, for as any politician or bureaucrat would hasten to tell you, these regulations are simply a reflection of the public will. Perhaps. But in the meantime, there is something that we can do to slow the rot if not stop it. In decreasing order of robustness these are: send a specimen to your local museum for identification, euthanasia and preservation as a permanent record; provide a photograph of at least one of the specimens you are observing, or at the very least state clearly in any report or publication just what the diagnostic (species defining) characters are for the species and verify that you have observed them.

Allen Greer

Zoologist

Mudgee, NSW

Graeme Gow was born and educated in Sydney, becoming interested in reptiles at an early age. He became Curator of Reptiles at Taronga Park Zoo in 1965 and was also Chairman of the Herpetology Section of the Royal Zoological Society of NSW. In 1973 Graeme moved to Darwin and resided there until his death. In 1974 he became Curator of Reptiles at the Northern Territory Museum and Art Gallery, and was a Field Research Associate of the Californian Academy of Sciences. After setting up the Noonamah Crocodile farm he opened "Graeme Gow's Reptile World" at Humpty Doo in 1982.

Graeme was well known for his numerous publications including "Snakes of Australia" and "Graeme Gow's Complete Guide to Australian Snakes". A list of his publications is set out below. He described two new species of snake, the Oenpelli Rock Python (*Morelia oenpelliensis*) and the Centralian Carpet Python (*Morelia bredli*). A skink, *Anomalopus gowi*, was named after him.

Rugby league was Graeme's other great passion and he was involved in the code at many levels over the years. In particular he had a big involvement with junior league and had great success coaching at a club and representative level.

In 2001 Graeme was diagnosed with cancer. Never a quitter he fought it with huge determination, underwent treatment and seemed to be winning. However it was not to be and he died at his home in Humpty Doo on the 12th August 2005. Graeme was known, respected and loved by many people both in Australia and overseas. Always available for advice or just a good yarn, he will be missed. Graeme is survived by his wife Suzanne and children, Stephen, Joanne, Lisa, Jason, Samantha and Michael.

Publications:

1973. Notes on the Taipan - (*Oxyuranus scutellatus*). Royal Zoological Society of New South Wales, Bulletin of Herpetology 1(2): 18-19.

1973. Notes on the Little File Snake *Acrochordus granulatus*. Royal Zoological Society of New South Wales, Bulletin of Herpetology 1(2): 20.

1976. Snakes of Australia. Angus & Robertson, Sydney. Reprinted 1980. Revised 1983. Reprinted 1985, 1986, 1989.

1977. Fanged but friendly. Darwin's colubrid snakes. Australian Natural History 19(3): 97-101.

1977. A New Species of Python from Arnhem Land. Australian Zoologist 19(2): 133-139.

1977. Snakes of the Darwin Area. Museums and Art Galleries Board of the Northern Territory, Darwin.

1980. History of the Taipan *Oxyuranus s. scutellatus* - with two new distribution records. Northern Territory Naturalist 1(3): 15-19.

1981. Checklist of the Reptiles and Amphibians of the Northern Territory. Northern Territory Naturalist 4: 16-19.

1981. Notes on the Desert Death Adder (*Acanthopis pyrrhus*) Boulenger 1898, with the first reproductive record. Northern Territory Naturalist 4: 21-22.

1981. A New Species of Python from Central Australia. Australian Journal of Herpetology 1(1): 29-34.

1982. Australia's Dangerous Snakes. Angus and Robertson, Sydney.

1982. A Herpetofaunal Survey of Groote Eylandt. Australian Journal of Herpetology 1(2): 62-70.

1989. Graeme Gow's Complete Guide to Australian Snakes. Angus and Robertson, Sydney.

NOTES TO CONTRIBUTORS

Herpetofauna publishes articles on any aspect of reptiles and amphibians. Articles are invited from interested authors particularly non-professional herpetologists and keepers. Priority is given to articles reporting field work, observations in the field and captive husbandry and breeding.

All material must be original and must not have been published elsewhere.

PUBLICATION POLICY

Authors are responsible for the accuracy of the information presented in any submitted article. Current taxonomic combinations should be used unless the article is itself of a taxonomic nature proposing new combinations or describing new species.

Original illustrations will be returned to the author, if requested, after publication.

SUBMISSION OF MANUSCRIPT

Two copies of the article (including any illustrations) should be submitted. Typewrite or handwriting (neatly) your manuscript in double spacing with a 25mm free margin all round on A4 size paper. Number the pages. Number the illustrations as Figure 1 etc., Table 1 etc., or Map 1 etc., and include a caption with each one. Either underline or italicise scientific names. Use each scientific name in full the first time, (eg *Delma australis*), subsequently it can be shortened (*D. australis*). Include a common name for each species.

The metric system should be used for measurements.

Place the authors name and address under the title.

Latitude and longitude of any localities mentioned should be indicated.

Use the Concise Oxford Dictionary for spelling checks.

Photographs – High resolution digital, black and white prints or colour slides are acceptable.

Use a recent issue of *Herpetofauna* as a style guide.

Electronic manuscript may be submitted to the editor via email or on a CD. It needs to be in Word format.

Articles should not exceed 12 typed double spaced pages in length, including any illustrations.

REFERENCES

Any references made to other published material must be cited in the text, giving the author, year of publication and the page numbers if necessary. At the end of the article a full reference list should be given in alphabetical order. (See this journal).

Manuscripts will be reviewed by up to three referees and acceptance will be decided by an editorial committee. Minor changes suggested by the referees will be incorporated into the article and proofs sent to the senior author for approval.

Significant changes will require the article to be revised and a fresh manuscript submitted.

REPRINTS

The senior author will receive 25 reprints of the article free of charge.



Flatworms (*Bdellasimillis barwicki*) in the inguinal pocket of a Johnstone River Turtle (*Elseya* sp.).
(Photo: G. Turner). See article on turtle ecology on page 41.



Rainbow Skink (*Carlia vivax*) from Sherwood Nature Reserve, New South Wales.
(Photo: G. Shea). See article on this species on page 27.